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U. S. DEPARTMENT OF AGRICULTURE.

Bureau of Chemistry---Bulletin No.___

H. W. Wiley, Chief of Bureau.

COMPARATIVE FERTILITY AND NITRIFYING POWER OF SOILS.

I. Methods of Experimentation

By

H. W. Wiley.

II. Relation of the Solubility of Potash and Phosphoric Acid in Soils to Crop Production.

By

C. C. Moore.

III. Studies of the Nitrifying Properties of Soils.

By

E. E. Ewell.

SEAL.

L E T T E R O F T R A N S M I T T A L.

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U. S. DEPARTMENT OF AGRICULTURE,

Bureau of Chemistry,

Washington, D. C., June 30, 1904.

Sir:

I have the honor to transmit herewith the data secured in this Bureau during the past eight years in the prosecution of studies on the relative solubility of plant food in soils and its relations to crop production and on the relative activity of the nitrifying organisms in soils, and to request that the report be published as Bulletin No. ___.

Respectfully,

H. W. Wiley,

Chief of Bureau.

Hon. JAMES WILSON,

Secretary of Agriculture.

C O N T E N T S

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Page

Introduction.....

Comparative fertility and nitrifying power of soils.....

I. Methods of experimentation..... 1

Statement of the problem..... 1

Review of pot culture experiments..... 6

Artificial conditions involved..... 6

Pot experiments in Germany..... 8

Dresden..... 10

Möchern..... 11

Darmstadt..... 12

Pot experiments in France..... 12

Pot experiments in England 14

Pot experiments in the United States.... 15

Connecticut..... 15

Massachusetts..... 15

Rhode Island..... 15

Objects of the experiment..... 17

Description of apparatus and methods..... 21

Pothouse..... 21

Trucks..... 22

Construction and manipulation of pots... 23

Selection of soil samples..... 25

Preparation of soil and planting..... 26

Watering of soil..... 26

II. Relation of assimilable phosphate and potash in soils to crop production..... 29

Page

Plan of experimental work..... 36

Method of culture..... 37

Watering records..... 41

Photographic records..... 43

Climatic data..... 44

Influence of heating upon the solubility of plant foods..... 45

Comparison of total crops with the amount of plant food found therein..... 48

Virgin soils..... 48

Cultivated soils..... 51

Muck soils..... 54

Duplicate cropping..... 55

Solubility of phosphorous and potassium compounds of the soil in water..... 58

Chemical results obtained on Rothamsted soils..... 61

Comparison of methods..... 61

General considerations..... 62

Mechanical composition of the soils..... 66

Method..... 66

Results..... 67

Chemical composition of the soils..... 68

Method..... 68

Comparison of crop yield and complete chemical analysis of the soil..... 70

Estimation of quickly available plant food..... 72

Method..... 72

Comparison of mineral composition of the crop with the estimated

available plant food..... 78
The feeding power of different crops 80
Details of proposed method..... 81

Fertilizer experiments..... 85
Experiments in plant feeding..... 90
Oat plants on virgin soils..... 90
Oat plants on cultivated soils..... 95
Cowpeas on virgin soils..... 100
Cowpeas on cultivated soils..... 103

Sampling of soils in the field..... 106

III. Studies of the nitrifying properties of soils 117

Introduction..... 117
Sources of soil fertility..... 117
Conditions necessary for nitrification.. 118
Development of nitric and nitrous acid in soils..... 120
Order of oxidation..... 121
Production of ammonia in the soil by the action of microbes..... 122
The nitrification of ammonia..... 123
Effect of potassium salts on rate of nitrification..... 124
Occurrence of nitrifying organisms..... 125
Determination of the nitrifying power of soils..... 126

Plan of the investigation..... 126

Soil sampling..... 127

The culture medium and seeding..... 130

Temperature conditions..... 132

Progress of nitrification..... 132

Page

Methods of testing for nitrous and nitric nitrogen..... 133
Preliminary tests with diphenylamin..... 133
Method for the determination of nitrous nitrogen..... 133
Method for the determination of nitric nitrogen..... 134

Discussion of results..... 135
Sample No. 5..... 136
Sample No. 15..... 137
Sample No. 17..... 137
Sample No. 29..... 138
Sample No. 30..... 138
Sample No. 33..... 138
Sample No. 53..... 139
Graphic presentation of results..... 139
Summary..... 140

General summary..... 143

I L L U S T R A T I O N S.

--oOo--

Page

Fig. 1 Pot house at Halle, August 1, 1898.....

2. Pot bearing sugar beets, Halle, August, 1898...

3. Pot house at Möchern, August, 1898.....

4. Deherain's arrangement for culture experiments studying drainage waters.....

5. View of pot house, Washington, D. C.....

6. Truck with pots and protective frame work.....

7. View of pot with device for protecting crop....

8. Section of pot.....

9. Crop photographs

a. Oats grown on soil No. 11 from 1896 to 1902

b. Beans grown on soil No. 9 from 1896 to 1900

c. Abnormal crops of oats grown in 1900 on soils 23 (Pot 76) and 43 (Pot 168).....

d. Cowpeas grown on soil No. 3 before and after addition of lime in 1901 and 1902 respectively.....

10. Apparatus for measuring water added to pots....

11. Shaking device for soil extraction at a constant temperature.....

12. Graphic representation of the rate of diminution of solubility with increase in depth in soil No. 3.....

Page

Fig. 13. Soil sampling machine.....

14. Apparatus for collecting and shipping soil samples for nitrifying experiments.....

15. Graphic representation of soil strata culture.. Nos. 301--332 (see table I).....

16. Nos. 333--364 (see table I).....

17 Nos. 365--396 (see table I).....

18. Nos. 397--428 (see table I).....

19. Nos. 429--460 (see table I).....

20. Nos. 461--476 (see table I).....

21 Laboratory for seeding and nitrifying investigations.....

22. Temperature chart for cultures Nos. 301--332, seeded May 3, 1895.....

23. Nos. 333--356, seeded May 9, 1895.....

24. Nos. 357--372, seeded May 18. 1895.....

25. Nos. 373--388, seeded May 27, 1895.....

26. Nos. 389--412, seeded June 5, 1895.....

27. Nos. 413--420, seeded June 19, 1895.....

28. Nos. 421--436, seeded June 26, 1895.....

29. Nos. 437--440, seeded July 13, 1895.....

30. Nos. 441--444, seeded July 19, 1895.....

31. Nos. 445--452, seeded September 10, 1895.....

32. Nos. 453--456, seeded October 12, 1895.....

33. Nos. 457--464, seeded November 19, 1895.....

Page

Fig. 34. Record of the progress of nitrification in cultures-- Nos. 305 and 305a.....

35. Nos. 315 and 315a. .....

36. Nos. 317 and 317a.....

37. Nos. 329 and 329a.....

38. Nos. 330 and 330a.....

39. Nos. 333 and 333a.....

40. Nos. 353 and 353a.....

41. Amount and character of nitrification in cultures..Nos..301--476.....

42. Nos. 317--332.....

43. Nos. 333--348.....

44. Nos. 349--364.....

45. Nos. 365--380.....

46. Nos. 381--396.....

47. Nos. 397--412.....

48. Nos. 413--428.....

49. Nos. 429--444.....

50. Nos. 445--460.....

51. Nos. 461--476.....

52. Nos. 301--385 (Series B).....

53. Nos. 389--473 (Series B).....

INTRODUCTION.

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This bulletin is the result of eight year's work in conducting investigations authorized by Act of Congress, approved August 8, 1894, making appropriations for the then Division of Chemistry, which reads as follows:

> To enable the Secretary of Agriculture to undertake a special investigation of the different typical soils of the United States to determine their chemical character, their physical properties, and especially the nature of the nitrifying organisms which they contain.

This language was repeated in the acts for the fiscal years, 1894 to 1901, inclusive. When the Division of Chemistry in 1901 was made a bureau, the work was reorganized and among the several laboratories into which the Bureau was divided were a soil and a fertilizer laboratory. On January 13, 1903, the Secretary of Agriculture united the above named laboratories, by the following special order:

> ********It is hereby directed that the Fertilizer Laboratory be combined with the Soil Laboratory of the Bureau of Chemistry under the title of Soil and Fertilizer Laboratory.
>
> ********The new laboratory shall be charged with the work conducted by the former separate laboratories, viz, investigations of all analytical and chemical problems connected with soil in respect of its composition and the relations of its compounds to the nourishment of plants: collaboration with the Association of Official Agricultural Chemists in the study of fertilizers: investigations of the best methods of analysis and of the availability of plant foods in fertilizers for plant growth; and investigations of the character of fertilizer and other substances used to correct soil acidity and thus promote the fertility of the soil by securing conditions of proper nitrification.
>
> This laboratory shall also be charged with all miscellaneous problems relating to the chemical composition of soils and fertilizers and their application to the needs of practical agriculture.

This report is offered at the present time in order that a permanent record of the work to date may be made and the data obtained be put in such form as to preserve a record of the work already done and as a suggestion to other workers along the same lines. It is true that not all the great problems involved in a research of this kind have been solved,

but it is believed that some progress in their solution has been accomplished. The Secretary of Agriculture has directed that after June 30, 1904, no further investigations of these problems be made in the Bureau of Chemistry and this action therefore terminates the research.

Our obligations are also due to the pathological and physiological investigators in the Bureau of Plant Industry, for valuable suggestions and assistance in the treatment of certain fungus diseases which attacked the growing crops, to the Division of Entomology for valuable assistance in freeing the crops from insect pests, and to the Bureau of Statistics for clerical assistance in the tabulation of the data.

It hardly seems necessary that an apology should be made for withholding the data from publication for so long a time, since the character of the problems under examination are of such a nature that they could not be elucidated by one or two years of experimental work. It is wiser to wait in such cases until data extending over a considerable number of years can be secured. The complexity of the problems makes it impossible that all the points which require elucidation should be fully discussed. There is yet a great amount of analytical work to be performed before a final word can be said concerning the questions under consideration. Many of the difficulties which at first presented themselves have been lessened or have disappeared altogether as the work progressed. On the other hand, many unforseen difficulties have presented themselves and demanded serious attention.

The merits and defects of the system employed are fully set forth in the bulletin. It is easy now, in the light of past experience, to see how the work could have been very much improved. It is hoped that even the faults and failures of the investigation may be fruitful of good in the future by showing at least the errors to be avoided. The great problems which underlie investigations of this kind have been plainly stated,

the data submitted are all that have been obtained and have not been selected for the purpose of sustaining any preconceived theories of any kind. They have been obtained by methods which are in general use, and whose accuracy has been fairly and fully tested. It is hoped that they have been presented in such a way as to be helpful to those who may hereafter undertake similar investigations.

H. W. Wiley,

Chief, Bureau of Chem.

COMPARATIVE FERTILITY AND NITRIFYING POWERS OF SOILS.

I. Methods of Experimentation.

Statement of the Problem.

It is evident that the production of a crop depends on many factors which together constitute the environment. Chief among these are climate, soils, and cultivation including fertilization. Assuming climatic conditions favorable to crop growth, namely, favorable temperature and a sufficient supply of moisture, it is evident that the magnitude of the crop will depend upon the character of the cultivation and the available plant food presented to the growing crop. If, again, we assume that the character of the cultivation also is favorable the magnitude of the crop will depend upon the amount, character and balance of the available plant food.

It has been established by exhaustive experiments that certain foods are absolutely essential to plant growth, while others are useful or of indifferent value. Among the essential foods are water, carbon dioxid, nitrogen, potash, phosphoric acid, iron, lime and magnesia. Among those of indifferent value as plant foods are silica, alumina, manganese, and many other elements found in the plant. Water and carbon dioxid, supplied as they are mostly by natural processes, are not usually included in a discussion of plant foods although they are perhaps the most important of all. Carbon dioxid exists principally in the atmosphere and is also evolved from decaying organic matter on, and below the surface of the soil.

The three most important plant foods which the farmer himself must supply, if they are not already present in the soil in sufficient abundance, are nitrogen, potash, and phosphoric acid.

Nitrogen is consumed by green plants only in the form of nitric acid. The soil has little or no adhesive attraction for nitric acid or nitrates in solution and hence these bodies are

most easily washed out by an over-abundance of water. Fortunately, however, the principal stores of nitrogen in the soil exist in an organic form insoluble in water. By the continued action of nitrifying organisms this nitrogen is slowly converted into nitric acid and thus becomes available continuously for the growing crop. It is evident, therefore, that in the estimation of the availability of nitrogen in the soil, not only must the store of nitric acid be determined, but also the total nitrogen existing in the organic form. This determination alone, however, would not give a correct idea of the availability of that nitrogen, and in order to secure this a study of the nitrifying organisms in the soil and the conditions on which nitrification depend is essential.

Since in the process of nitrification it is important that some base be present with which the nitric acid formed may combine, it is evident that the presence of lime in an arable soil is of great importance. The lime, existing as it does chiefly in the form of carbonate, presents itself to the nascent nitric acid in a convenient form for the assimilation thereof, producing nitrate of lime and setting free carbon dioxid. The moment a soil becomes strongly acid the process of nitrification is hindered and will finally cease. Hence, even if the lime in the soil be not important as a plant food. it is necessary in order to maintain a condition favorable to the progress of nitrification.

The potash and phosphoric acid of soils may be conveniently classed as existing in three distinct states. This does not refer so much to their form of chemical combination as to the relation they bear to the crop itself. First, we might consider the total amount of these plant foods in the soil in all forms; second, the amount of these plant foods existing in forms which slowly decompose and yield their elements to the plant; and, third, that portion of these food elements existing in the soil in a state already suitable for assimilation. It is evident that a soil may contain a very small quantity of phosphoric acid and potash and yet these may exist in such a

form as to abundantly supply the needs of at least one crop, although a second crop would not find sufficient food. The ideal condition would be for these elements to exist in large quantities, in combinations subject to progressive decay and yielding from year to year the amounts of potash and phosphoric acid needed. The quantities of these bodies removed per acre vary with different crops and different seasons, but the ordinary limits of removal may be said to lie between twenty and one hundred pounds. A progressive decay of the mineral forms in which these elements exist yielding from 20 to 100 pounds per year per acre, would be an ideal method of supplying throughout a series of years the plant food needed. Fortunately for the agriculture of the future, these plant foods exist also in mineral forms resistant to disintegration and decay, and hence large stores of them are held in the soil for the use of future generations.

Again, it must be considered that the surface of the soil is not stable. In some cases there is an accretion of the soil by disintegration on higher sections and the bringing of the disintegrated particles to the lower levels. Corresponding to this there is a degradation of the surface soil of the higher levels, exposing lower layers. Hence, the total amount of plant food available must not be regarded as being confined to one or two feet of the earth's surface, for these stores may be available even to greater depths. Geologists teach us that many portions of the earth's surface are now hundreds, or even thousands, of feet lower than they were in early geological times, while corresponding portions are higher. The glacial ice, ground and comminuted immeasurable quantities of the earth's crust and distributed it over wide areas, filling ravines, valleys and gulches, and leaving the surface of the earth comparatively level. Smaller streams and rivers carry immense quantities of silt annually to lower levels and deposit them as alluvial drift. Thus continually additional quantities of plant food are made available.

Objection has been made to the chemical study of soils on

the ground that it does not lead to any practical results in predicting fertility. Happily, it is not necessary to depend upon chemistry alone, or any other science, to determine soil fertility, since the growth of a single crop under favorable conditions will establish that point. Chemical analysis, however, will undoubtedly show the total quantity of plant food which a soil contains, and modifications of methods, as shown in the results of experiments, will give valuable indications respecting the amount of food available. Agricultural chemists have worked along various lines in the effort to determine this point, and all of these researches have led to advances in the art of predicting or determining the amount of available food present. The most promising of these methods are those which consist in the use of dilute solutions of organic acids, such as citric and aspartic, or the use of very diluted mineral acids, such as a weak solution of hydrochloric acid, as solvents. The latter has been used largely in obtaining the data recorded in this bulletin. Each of these methods has its advantages, and to each valid objections may be made. The results, however, which are recorded in this bulletin are sufficiently conclusive to plainly indicate that when other conditions of the environment are favorable, chemical methods determine approximately the quantity of immediately available plant food which the soil contains in respect of potash and phosphoric acid, to which elements the work has been chiefly confined.

One point chemistry settles definitely, namely, that if a single one of the essential elements is absent, the production of a crop is impossible, even if all the other elements are present in an available form and in the greatest abundance. It is thus determined by chemical research that there should be an even balance in the ration of a plant, that is, all the elements must be present in an available form in at least a sufficient quantity, and when this is the case, and an otherwise favorable environment exists, an abundant crop will result.

It is undoubtedly true that the mineral substances absorbed from the soil have an important function in plant growth

aside from serving as foods. They modify profoundly the functional activity of the plant cells. Potash favors the formation of carbohydrates especially, and phosphoric acid the formation of protein and fats. The plant has well-defined mineral hunger which must be supplied in addition to its need for essential food. The mineral substances in the juices of the plant profoundly affect the circulation thereof. By reason of the dilution to which they are subjected, the mineral plant foods are doubtless easily disassociated into an ionized condition and are thus better fitted to form new combinations when they enter the plant. The circulation of the plant juices is largely influenced by the forces developed in the transfusion of liquids through membranes. Thus, if mineral substances had no functions as plant food they would still play a most important role in the life history of the plant.

Various theories have been advanced concerning the solubility of the mineral substances and their entry into the circulation. Among these may be mentioned the influence which the acid juices of the plants themselves exert. In this connection, however, it must be remembered that any such influence could only be exerted in immediate contact with the rootlets themselves, as the quantity of acids exuded by the plants from their roots is not such as to permit its soluble influences to reach any great distance from their periphery. The currents flowing in the soil are mostly to, and not from, the root systems. This fact is shown in the study of the erosion produced for instance on a piece of marble by the roots of a plant. The grooves formed by the erosion are confined strictly to the points of contact with the rootlets, while the rest of the marble surface remains unaffected.

It is evident, therefore, that the chemical solution which takes place in the soil, aside from the particles in contact with the roots, must come largely from the solvents in the soil itself. The principal solvent is undoubtedly water. Pure water, however, does not have, by any means, the solvent effect upon some minerals that water charged with other sub-

stances. Thus one active force in rendering soluble the plant food in the currents which reach the rootlets is the water in the soil carrying the ammonia and nitric acid absorbed from the air or derived from nitrification and mixed with the various substances mentioned above.

All these complex interrelations were kept in mind in planning and conducting the experiments discussed and in the following pages the results obtained are considered in the light of the nature and number of the modifying factors in the problem. An accurate record of the work of eight years of patient investigation and the advances made both in methods of work and knowledge of the problems involved are indicated.

REVIEW OF POT CULTURE EXPERIMENTS.

Artificial Conditions Involved.

The growth of plants in pots has been practiced for various purposes from the earliest times. Plants which are injured by exposure and the vicissitudes of the seasons are kept in pots so that they may be exposed during favorable weather and placed under cover when the meteorological conditions are harmful. For cultures conducted under glass to force plant growth or secure special results during the winter month pots are generally used as well as for preparing plants of all kinds for transplanting at favorable seasons. For strictly scientific purposes pot cultures have been in use for only a hundred years or less.

There are many kinds of experiments in which pot cultures are almost a necessity. There are, however, important objections to them from a practical point of view and the results obtained must always be interpreted with reference to the artificial conditions to which the growing plants have been subjected. In the first place the essential difference between pot culture and ordinary culture is found in the fact that the quantity of soil available for the nourishment of the plant in the former case is strictly limited. Whatever plant food

may be present in the potted soil, remains the only source of nourishment aside from artificially added materials. Under ordinary field conditions this is not the case. The plant roots may, and do in point of fact, extend to great distances, both laterally and vertically, in search of foods. The movement of the water in the soil favors the transportation from great distances of soluble plant foods in a state suitable to absorption. Each application of water to the surface of the soil produces profound disturbances in the currents which flow through the soil particles. Where the precipitation is excessive a downward movement is produced by the force of gravity. When the surface of the soil becomes drier, an upward and lateral movement is produced by capillarity. When acted upon by the absorbing properties of plant rootlets the supplies of soluble plant food in the neighborhood of the roots become diminished and additional quantities are brought to supply their place. Soils exposed to ordinary meteorological conditions continue to decompose and thus to release particles of plant food hitherto inaccessible. In pot culture, where the conditions to which soils are exposed remain practically uniform, the tendency to weathering or decomposition is diminished. Especially is this so when pot cultures are continued only during the growing season, as was the case with those which are to be hereafter described. During the winter months the soil is then left dry, under cover, and thus protected from the decomposing action of frosts and other disintegrating forces. It can be said that during the whole winter, from the time of harvest in the autumn until the time of planting in the spring, the soil undergoes but little change.

For all these reasons it happens that the available quantities of plant food in a potted soil disappear with far greater rapidity than they would in the same amount of soil in the open field. The conclusions, therefore, which are drawn from such experimental work must always be referred to the changed conditions before being applied rigidly to normal conditions in the open field.

Pot Experiments in Germany.

It will be of value in this connection, without entering into an elaborate discussion of the subject, to refer more briefly to the more important pot cultures which have taken place of late years in Europe. Wholtmann and Scheffler,[a/]

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a/ Berichte ad. physiol. Laboratorium und d. Versuchsanstalt d. Landw. Instituts d. Univ. Hall, 1891, 8.

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instituted a series of pot experiments in order to study the effects of fertilizers on different plants. Certain improvements in the methods of conducting the pot experiments were developed. Wagner, at Darmstadt, as before stated, uses zinc cylinders which are placed upon small tram-cars so as to be conveniently handled and run under cover when necessary for protection from storm or frost. Wohltmann objects to the use of pots of this kind, which are essentially the same in principle of construction as those which were used in the experiments described in this bulletin. The chief objection urged is that the pots are exposed on all sides to the action of the sun and thus conditions of temperature are produced which are entirely abnormal. This is a valid objection to such experiments, as is evinced in the fact that in our own work, after having tried the exposed pots for two years, it was decided to protect them from the lateral effect of the sun's rays by the protecting covers which will be described later.

Wohltmann's other objection, that the soil is not sufficient for the normal development of the roots, is hardly a valid one when it is considered that the object of the experiment should be, and is, to test only the particular quality of soil which the pot holds. If the roots of the plants be allowed, as in nature culture, to extend to any distance it is evident that the effect of the particular part of the soil in which they are growing is only a partial one, taken in connection with the whole plant growth, and that portions of soil at quite a distance therefrom may be equally important in

objections to the ordinary forms of pot culture by using zinc boxes 85 centimeters wide and one meter deep. The superficial areas of the box is 0.4 of a square meter. The zinc is protected by asphalt varnish, and to secure normal temperatures the boxes are sunk in the earth to the level of the ordinary soil. As a check upon the experiment the same plants are grown in portions of the natural soil intervening between the boxes as are grown in the boxes themselves. The water supply is from below and the amount of water added to the box is guaged by the height of the water in an external glass tube connected with the inside of the box. In the case of a very sandy soil this method would be perhaps satisfactory, but for an ordinary soil, experience has shown that it would be useless. Deep trenches are provided near the boxes so that the drainage of water can be collected.

It is evident that an arrangement of this kind can only be practiced on a limited scale owing to the great cost and labor of installing the boxes and supplying the soils, especially if they are to come from a great distance. It is also evident that no artificial control of the meteorological conditions prevailing is possible. The plants, of course, receive the natural rainfall, are exposed to all the vicissitudes of the season, and the only advantage for having the apparatus for adding water is to provide against a drouth. In the experiments described by Wohltmann, the boxes were found to leak, the labor involved in their care was great, and after three years of work the investigations were given up. A full discussion of the results of these pot experiments may be found in the Experiment Station Record.[a/]

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a/ Vol. 3, pages 342 and following.

The late Dr. Max Maercker also conducted for many years extensive pot experiments at Halle. This experiment station was visited by the writer in 1898. The same style of pot experiment as practiced by Wagner and in this Bureau is conducted

at Halle, as will be seen from the phorograph (fig.1) made at the time of the inspection.

There is one additional fixture at the Halle station to which particular attention is called, and that is the method of screening the pots from the direct rays of the sun. The area in which the pots are held is enclosed by posts with appropriate fixtures by means of which a cloth covering can be stretched around the sides, thus keeping out both the wind and the lateral rays of the sun. The top of this area is also covered with a light cloth which protects the pots partially from the direct rays of the sun. The principles of construction are essentially those to be described for the experiments of this Bureau. A clearer view of one of the pots bearing sugar beets is shown in fig. 2. As will be seen from the photograph, the pots at the Halle station are all conical in which respect they differ from those of our experiments which are cylindrical in shape.

Extensive pot experiments have also been made at Thurgau by H. Müller.[a/] These experiments were for the purpose of determining the action of various fertilizers on different plants and the arrangement of the pots presents nothing novel.

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a/ Jahresbericht der Versuchsstation, Wödensweil, 4, 52.

Dresden

At Dresden it was also deemed advisable to have the pots or boxes for the soils practically all the same size, representing a cubic meter, which was in fact larger than those used by Wohltmann and Scheffler. The boxes are made of cement and lined with glass. Plates of glass 1.3 cm. in thickness are put together in a cubical box to serve as a mold, and a cement cast around them of a thickness of 8.7 cm. The joints of the glass are made with red lead putty. The water is introduced artificially from the bottom, as in the previous case mentioned, and provision is made for drainage.

In filling the boxes a layer of gravel is first laid on the bottom and on this is placed a layer of sand to a height of 20 or 25 cm. and then the soil with which the experiment is to be made is put in. Passages between the boxes are arranged for the collection of the drainage, etc. These passages are from 1.8 to 1.9 meters deep and 1.5 meters wide and are so built as to provide for a gentle incline toward one point though the water falling in them will run and be conducted away by proper drains, or into a bed of gravel. The boxes holding the soils are, however, so arranged as to be surrounded on all four sides by earth.

A detailed description of the construction of these boxes is found in the Experiment Station Record.[a/]

[a/] Vol. 3, page 352 and following.

The objection to this style of work is the same as that before mentioned, namely, the great cost of labor and the comparatively few samples which can be studied. It is stated that the cost for installing twenty boxes as described is not far from $1,000. A similar station at Tharand, closely affiliated with the one at Dresden, has boxes of the same general type.

Möchern.

The experiment station at Möchern under the direction of Dr. Kellner is also provided with appliances for conducting pot cultures which in the main are the same as those used at Darmstadt, Halle, and at Washington. During the summer of 1896 the writer visited this station for the purpose of studying the technique of the process. A photograph made at that time is reproduced as fig. 3, and shows the arrangement of the pots.

Darmstadt.

Extensive exp riments have been conducted for many years at Darmstadt under the direction of Dr. Paul Wagner, the director of the agricultural experiment station at that place. I visited the station in 1898, three years after instituting the experiments described herein, and made a careful study of the technique of the process.

The Darmstadt station is arranged almost exactly on the same principle as that of the one at Washington. Small pots with limited quantities of soil are used, the pots being carried upon tram-cars and so arranged as to be run under cover at any moment. The value of this method of experiment consists largely in the fact that so many different samples of soil can be treated with small expense, while it is admitted that the conditions are more artificial than those of the experiments just noted. The amount of information derived from work of this kind is so great, and the comparative value of the experiments so decisive, as to render this method of pot experiment upon the whole preferable to the more ponderous method of heavy boxes sunk in the soil.

Pot Experiments in France.

Extensive experiments have also been conducted in France in boxes or pots, among which, those carried on by the late M. Deherain at the agricultural experiment station of Grignon are notable. This station was also visited in 1898 and the methods in vogue there were studied. A description of the method, which is essentially the same as those of the large box experiments in Germany is given below:

> Deherain's earlier experiments were made in pots containing about sixty kilos of soil. These vases serve very well for some kinds of plants, but there are other kinds which do not grow at all normally when their roots are imprisoned. For instance, in pots, even of the largest size, wheat is always poor, beets irregular, maize never acquires its full development, and the conclusions which can be drawn from the experiments cannot be predicted of the action of the plant under conditions entirely normal.

It is necessary therefore to carry on the work in an entirely different way, and to construct boxes so large as to make the conditions of growth entirely normal. The arrangement of these boxes is shown in fig. 4.

They are placed in a large trench, two meters wide, one meter deep, and forty meters long. There are twenty boxes in this trench, the upper surface of each containing four square meters area. The boxes are one meter deep, and therefore can contain four cubic meters of soil. The sides and bottoms of the boxes are made of iron lattice work, covered with a cement which renders them impervious to water.

The bottom inclines from the sides towards the middle, and from the back to the front, thus forming a gutter which permits of the easy collection of the drainage. The drainage water is conveyed, by means of a pipe and a funnel, into the demijohn placed in the ditch in front of the apparatus, as shown in the figure. These receptacles stand in niches under the front of the cases, and are separated by the brick foundations. Access to them is gained by means of the inclined plane shown in the figure, and this plane permits the demijohns in which the drainage water is collected, to be removed with a wheelbarrow for the purpose of weighing. This apparatus is especially suitable for a study of the distribution of the nitrogen to the crop, the soil and the drainage waters. The loss in drainage waters of potash and phosphoric acid is insignificant in comparison with the loss in nitrogen.

The cases having been placed in position they are filled with the natural soil, which is taken to the depth of one meter, in such a way that the relative positions of the soil and subsoil are not changed.

While the soil is transferring to the cases it is carefully sampled in order to have a portion representing accurately the composition of both the soil and the subsoil. These samples are subjected to analysis and the quantities of nitrogen, phosphoric acid, and potash contained therein carefully noted.

One or two cases should be left without crop or fertilizer to determine the relations of the soil and subsoil to the rainfall. Three or four cases should be kept free of vegetation and receive treatment with different fertilizer, in order to determine the influences of these on the deportment of the soil to rainfall. The rest of the cases should be seeded with plants representing the predominant field culture of the locality, and some of them should be fertilized with the usual manures used in farm culture.

In connection with his studies upon drainage water Deherain made extensive experiments with glazed earthen-ware pots.[a/] The opening is made in the bottom of the pot into

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[a/] Annales Agronomiques, 16; 337; 17; 14; and 19; 89.

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which a tube is fitted leading into a flask. The pots are supported on iron standards in such a way as to allow for the convenient insertion of the flask. These pots are not protected in any way and consequently will reach a higher tem-

perature in the summer time than soil in situ. In order to partly protect the pots from the action of the sun they are placed in a trench, two meters deep, one meter wide, and forty meters long. It was to avoid this difficulty that Deherain constructed the form of experiment described above. The crops grown by Deherain were oats, hemp, peas and clover.

A. Pagnoul[a/] has also made experiments with pots in the

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a/Annales Agronomiques, 1892, Vol. 1, No. 2, 237.

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growing of potatoes. Pagnoul's experiments were confined largely to the growing of potatoes in sand and were instituted particularly to determine the effect of potash upon the weight produced and the quantity of starch. The result of the experiment showed that with the aid of potash the amount of tops produced was doubled and the amount of tubers increased threefold, while nitrogen in the form of nitrate gave a larger crop of tubers than in the form of ammonia, and that nitrate of potash was superior to nitrate of soda, a result easily explained by the presence of the potash rather than the greater availability of the nitrogen.

Pot Experiments in England.

Extensive series of experiments have been conducted at Rothamsted, by Laws and Gilbert, which are described in full in the Memoranda of Field and Other Experiments Conducted at Rothamsted, which memoranda have been published from time to time as a record of the general experiments of this celebrated agricultural experiment station. Large areas of soil were isolated by digging around and under them, inserting casings which were permeable only on the under surface. No artificial irrigation or protection of the growing crop was provided for, the chief object of the experiments being to study the relations of the isolated masses of soil to crop production and especially to secure and study the drainage waters. This

station has also been inspected and its technique carefully studied by the writer.

Pot Experiments in the United States.

At quite a number of the agricultural experiment stations of the United States extensive pot cultures have been conducted.

Connecticut.

At the Connecticut station[a] a series of experiments has been inaugurated to determine the availability of nitrogen in various forms for grass growing. Grass was grown in galvanized iron pots filled with soil which had not been fertilized or cultivated in many years. The fertilizers used were nitrate of soda, cotton seed meal, raw soft bone, raw hard bone, and steam bone. The pots were cylindrical in shape, made of galvanized iron, eight inches in diameter and twelve inches deep. Each pot carried a glass tube, reaching from the bottom to the top for ventilation and use in watering. The pots were placed under glass to protect them from rain, wind and insects.

[a] Annual Report, 1898, page 299, and 1899, page 197.

Massachusetts.

Experiments in pot culture have also been conducted in Massachustts[a] with onions, potatoes, soy beans, Indian corn, and millet. In all 286 pots were used for these experiments but no complete report of the work has yet been made.

[a] Hatch Experiment Station Report, 1900.

Rhode Island.

In the experiments at the Rhode Island[a] station prior to 1897 galvanized iron pots were used which were sunk into the

[a] Agri. Exp. Sta. Report, 1897, 171.

ground to within two inches of their tops. The soil in the pots was filled in to the level of the external soil. This adjustment of course was made in order to secure normal conditions of temperature, etc., in the pot experiments, but the arrangement was found unsatisfactory.

From 1893 to 1897 there were conducted in these pots a series of experiments to determine the relative assimilability of various forms of nitrogen upon acid, limed, and unlimed, soils. Barley, rye and oats were grown. The results show that in an acid soil, where nitrification progresses slowly, nitrogenous fertilizers, consisting of blood and fish, are practically wasted. The pot experiments after 1897 were transferred to above-ground pots placed under glass and the experiments were made particularly to test the probable assimilability of the phosphoric acid in the form of ignited alumina-phosphate as compared with the phosphoric acid in bones and in the form of "floats." The experiments were also continued for the purpose of ascertaining how far the difference in action of nitrate of soda and sulphate of ammonia upon the growth of certain plants is attributable to the condition of acidity of the soils. A series of experiments in pots has also been conducted at the Rhode Island station for comparing the results secured with these in the cooperative field experiments throughout the State.

Another set of pot experiments has been conducted to determine the after effects of sulphur when used as a preventative of potato scab, and to ascertain the effect of the deficiencies of magnesia in soils. In 1899 there was installed a system of pots placed upon tram-cars, similar in structure to those used in the experiments reported in this bulletin. Since that time the work in pot culture has been continued at the Rhode Island station for various purposes.

Many other experiments in pot culture have been made, both in Europe and this country, but the references which have been given are sufficient to illustrate the general character of

such work. Its value, when properly interpreted, is without question, and the perfect control over the environment which it makes possible enables the experimenter to study problems which without such control would be too complex for solution. If the data are interpreted as has been indicated, with due regard to the artificial conditions which obtain, they cannot fail to be of the highest interest both from a scientific and practical point of view.

Objects of the Experiment.

The term "typical soil" as used in this report does not refer to any particular kind of soil in respect of its geological origin or chemical composition but is used to describe the types of soils which are under cultivation in some of the experiment stations of the country. The object in securing these soils was not to get samples representative of the general character of the soil over a considerable area but to obtain samples of soil en bloc for the purposes of studying the crop-producing power in comparison with its chemical and physical structure.

In the chemical study of soils the conduct of the work and the character of the examination depend upon the object in view. If the origin and nature of the soil in respect of the materials from which it has been derived are the subjects of investigation a complete analysis will throw the desired light upon its constitution. The composition of the original rocks or of those similar thereto from which the soil has been derived compared with the chemical composition of the soil itself will show the changes which have taken place in weathering, the quantity and kind of materials removed by leaching, and the composition of the residual portions. The geological data relating to the locality and the character and distribution of the plants growing upon the soil in its virgin state are also matters of great interest. Such studies as these lie at the very foundation of all scientific knowledge of the

soil itself and should never be neglected, when any question arises concerning the changes which the materials furnished by the soils have undergone. These changes, as is well known, are very slow in action and have extended over indefinite periods of time. Such studies have their maximum comparative value only when the soils have been chiefly formed in place and not when they have been deposited as the result of the action of the wind, carrying particles in the form of dust, or by the erosive and translating power of water along the streams and rivers, nor when the deposit has been due to the action of moving ice, as illustrated by the great drift areas of the glacial periods. Soils which have been deposited in the ways last mentioned have a composite quality which makes it difficult to trace their origin, or to compare them directly with the rock substances by whose disintegration the principal part of the material composing them is formed.

The study of the soil from the point of view of its composition and origin is intimately related to geology and mineralogy and forms the connecting link between scientific agriculture and the sciences which treat of the nature of the topography and composition of the surface of the earth and the minerals found therein. The importance of a study of this kind should not be underrated, since no complete system of scientific agriculture can be constructed, which does not rest upon the fundametal basis of the intimate knowledge of the character of the soil, the sources from which it has been derived and the processes by which it has been made.

The term "typical soil," therefore, can be used in many senses. From the point of view just stated a typical soil is one which represents the results of the weathering of the different rock formations, such as limestone and granite. Inasmuch as there are many different varieties of limestone and granite there can be different soils formed by the weathering of these rocks or others of a typical nature. It is evident that such a typical soil as has been mentioned is found

in situ, and has been subject to practically no disturbance by wind, water or ice, in so far as translation of its particles is concerned and that this soil has preserved in a more or less unchanged state, as respects its chemical composition, the insoluble matters, which are the residue of the decomposed rock, from which it has been formed. In still another sense the term "typical soil" can be applied to the general characteristics of the soil in question. Thus we have a typical clay or a typical sand soil, a loam or a gravel soil, etc.

Returning to the principle objects which have been kept in view in the following studies attention should be called first of all to the study of the proportions in which the principal plant foods required for the nourishment of the crops may be found. In a case of this kind the chemical studies are usually not extended to the less important forms of mineral constituents in soils, but rather to those which are essential, such as phosphoric acid, potash, lime, magnesia, and nitrogen. To determine these substances it is seen that a complete mineral analysis of the sample is not required, but, on the other hand, it would be sufficient to extract and determine the substances which are most essential to the nourishment of the plant. To this end, various methods of procedure have been proposed depending upon the greater or less solubility of plant foods in solvents, the greater or less strength of the particular solvent and the influence of the temperature upon the rates of solution. Such a study of soils does not give absolute but rather comparative data, since the amount of material extracted in any given case depends not only upon the amount originally present in the sample, but also upon various factors which must be controlled in different ways. As for instance, the strength and character of the solvents, the temperature at which they act, the time during which the sample is subjected to their action, the agitation to which the sample is subjected during this time, and other influences. If all these factors are not controlled in the same way the data obtained by different investigators would naturally be very

different in character and the conclusions reached would be equally as various.

It must furthermore be recognized that the chemical and physical data which are obtained by any kind of examination must not be regarded as absolute criteria in determining the properties of the soil. The results of such examination should be checked by actual experimental growth of crops upon the soil in question. In order to eliminate all the disturbing factors of different environments in such experimental work it is necessary to subject the crops to exactly the same conditions with the exception of the soil itself. To this end, samples of the soil must be assembled from different localities and crops grown upon them under uniform conditions. In order to secure these conditions, an experiment pot house was constructed, a description of which will be given later, where the soils from the different experiment stations were put in pots and placed upon tracks on minature railways. Thus all the conditions of the growth, except those inherent to the soils themselves were under perfect control.

Since one of the most important of the plant foods is nitrogen a special study of this element was undertaken in connection with these investigations. As the nitrogen is only consumed by the green plant in the form of nitric acid an important part of the study of the soil relates to the number and activity of the nitrifying organisms contained therein. Inasmuch also as there are denitrifying organisms contained in the soil which decompose the nitric compounds into their elements, including free nitrogen which is thus wasted, the importance of these organisms must not be overlooked. The whole of the work, therefore, would be naturally divided into the following heads:

1. Construction and equipment of the pot house, together with a study of the form of pots and methods of handling which will secure the best results.

2. The collection of samples from different localities

representing wide limits of latitude and longitude, and presumably wide variations in the character of the soil under cultivation.

3. The sampling of the soils at different depths in sterilized tubes for the purpose of making cultures to determine the number and activity of the nitrifying organisms therein contained.

4. Chemical and physical studies of the soils by various approved or proposed processes to determine the total amount of plant food therein contained, and in so far as possible, the quantity available for the immediate uses of the growing plant.

5. The growing of different crops in the potted soils under standard conditions and a comparison of the amount of crop produced and the food materials contained therein with the composition of the soil itself, as determined by various processes

6. A study of the rate of the exhaustion of the soils under continuous culture as determined by the magnitude and composition of the crops produced.

7. A study of the methods of restoring the soil wholly or in part to its original state of fertility. Many of these problems have been studied incidentally in the following pages, the greater part of the work having been devoted as previously intimated, to the relation of the potash and phosphoric acid, extracted by different solvents to the magnitude of the oat crop, and to a preliminary study of analytical methods of ascertaining the nitrifying activity of the organisms in the soil.

Description of Apparatus and Methods.

Pot House.

The pot house is of simple construction and is 40 feet long, 22 feet wide, and 9 feet high to the roof. It is built on the grounds of the U. S. Department of Agriculture and so placed that the rays of the sun can reach the yard of the house at all hours of the day except very early in the morning and very late

in the afternoon. The west front of the house is laid with tracks for handling the trucks holding the pots. Each track carrying the trucks enters the house through a double door. The attic of the pot house is used for drying and storing crops when harvested and the shelving within the house for holding the samples of soil secured for analytical purposes. The room is also provided with a shelf and locker used for making and keeping the agricultural notes. A differential pulley for lifting the pots for weighing is fastened on a running bar so that it can be used at the center of each track from door to door of the building. There is also a water supply, wash-basin, etc., for the convenience of the attendants in charge. A view of the pot house is shown in fig. 3.

Trucks.

The trucks consist of an iron frame resting on four wheels. In this iron frame is built the wooden support for holding the pots. In order to protect the pots from the heat of the sun during the hot days of summer a covering of boards painted white is provided so that the rays of the sun strike directly on the board, and the surface of the pot only. At the same time this protection is so arranged that the bottom of the pot is of easy access, and any drainage which may pass through is collected and returned to the pot. This arrangement gives a perfect protection to the pots from the sunlight, and at the same time does not interfere with their removal for weighing, with the application of water, or with the recovery of any drainage. The construction of the complete truck with its pots and protective frame work is shown in fig. 6.

At the west end of the yard a depressed track carries a switching car by means of which any truck can be switched from one track to another, or carried directly to the door of the photographic house, a small room built directly west of the pot house. The tracks are constructed of very light railroad iron built on cross ties embedded in sand. The photographic

house is supplied with screens; glass roof, screened; dark room, and all necessary appliances for photographic work. This house and a car being transferred thereto are shown in fig. 5.

Construction and Manipulation of Pots.

Many methods of pot construction were tried in order to determine the best arrangement for securing results, applying water, effecting drainage, and manipulating the pot itself. The first method of application of water tried was the insertion of a perforated tin cylinder in the center of each pot into which the water was poured, finding exit in the soils through the perforations which extended from two inches below the surface of the soil to about the depth of eight inches. This method of applying water was found to work very well with most soils. There were some dense soils, however, of a fine clay texture which it was found quite impracticable to irrigate in this way and the method was abandoned after a thorough trial. The method of construction finally agreed upon was as follows:

The pots are made of galvanized iron and are 13 1/2 inches deep and 12 inches in diameter. They rest upon a tripod of heavy iron and their general appearance is shown in fig. 7.

As the crop growing in the pot increases in size it is the subject of damage from wind, having no support by reason of the proximity of similar growth, as is the case in cultures in the open field. Birds and insects also injure the flower and maturing seed, and protection must be secured against these evils. To this end the crop is protected by a wire frame work over which mosquito netting is spread, as shown in fig. 7.

The construction of the interior of the pot is shown in the section in fig. 8. Nearly half way to the top a cylinder box, shown in section as AA, is soldered to the external surface of the pot and connecting with the interior by a series of small perforations. This compartment holds conveniently one liter but may be made to hold more or less. The water is added through a funnel shaped attachment B closed by a lid C. On

the interior of the pot and immediately below the orifice connecting the cylindrical box described above is soldered a circular shelf D about 1 1/2 inches wide. This shelf is for the purpose of holding cotton which is packed around it covering the orifices in such a way that when the pot is filled with soil the orifices are not occluded.

It is thus seen that the water which is added to the box AA passes out through the orifices and becomes absorbed first by the cotton and then the water passes on to the soil, moving upwards by capillary attraction to moisten the part above the shelf and downward to moisten the part below. The bottom of the pot is so constructed as to incline slightly towards the center from all parts. The central portion is perforated in order that any excess of water which may be added above the amount necessary to saturate the soil may pass through its perforations and be collected in the pan placed underneath them, to be returned to the pot through the funnel shaped attachment B. Several years of experience have shown that this method of applying the water is entirely satisfactory. It avoids the packing and baking of the surface of the soil which takes place when the water is added directly from the top. At the same time it permits the introduction of the proper amount of moisture at the spot where the roots are most vigorous and where they most need it. The principal objection to a pot of this kind is the cost of its manufacture which of course, exceeds that of a simple pot without any of the attachments named.

The bottom of the pot is first covered with a layer of very coarse gravel or broken stone to a depth of about two inches. The soil to be experimented with is then added carefully so that the pot is filled in up to and over the projecting shelf and then tamped. Cotton is placed around the shelf in the manner described above until the orifices through which the water is to pass are entirely protected. In filling the pots the soil should be gently shaken until they are filled up to within one and one half inches of the top of the pot. When

the soil is properly filled in this way, after tamping and shaking, it settles very little more and leaves no appreciable crevices underneath the shelf. The soil before potting is air-dried and carefully mixed so that it can be handled without any danger of changing its texture and is used in an air-dried state. Each season the soil is all removed from each pot and remixed and the pot is repacked at the beginning of the next season. Experience has shown that the shelf should not be half way down the pot, but should be near the top; a point between one-third and one-fourth of the distance from the top to the bottom is about the best.

While, as has been said, this pot has been found to give entire satisfaction, except in the case where the soil is of so fine a texture as to be practically impermeable to water, yet upon the whole, the old fashioned simple pot without any appliances will serve for experimental purposes almost as well as one of elaborate construction and in many cases better. The only care to be taken in watering the pots directly from the top is that the surface of the soil should be stirred occasionally, when sufficiently dry, to prevent baking. There is one advantage in watering the pot directly from the top and that is it is more nearly like nature's method of applying water in actual cultivation. If the soil experimented with were of an alkali nature, a pot such as described would tend to accumulate the alkali near the surface by evaporation of the water.

Selection of Soil Samples.

The soils were selected and sampled by the experiment stations in the States represented. In this selection the purpose was to obtain types, as nearly as possible, representing general, rather than extreme, conditions of fertility. In 1894 a circular letter was addressed to the various experiment stations as follows:

> It is proposed to undertake in the Division of Chemistry a comparative study of the typical soils of the

different parts of the country for the purpose of comparing the experimental growth therein with the composition as determined by the various methods of chemical analysis. We desire the cooperation of your station in this work in the taking of samples in harmony with the enclosed directions.

The success of the work depends upon the active cooperation of the various agricultural experiment stations and I shall be glad to learn of your willingness to supervise the taking of the samples as required.

(Signed) C. W. Dabney,

Assistant Secretary of Agriculture.

The accompanying directions for sampling the soils were as follows:

A pit with straight walls should be dug, the sides of which are at least two feet wide. By the means of a spade the surface soil should be removed from the four sides until the change of color between the soil and the subsoil is noted. In all about 150 pounds of air-dried soil are required. In the same way take a sample of the subsoil to the depth of 9 additional inches. Remove all stones, large pebbles, sticks, roots, etc., and spread the samples in a sheltered place where they can be air-dried as rapidly as possible. When air-dry, place in a clean bag, and pack the bags in boxes for shipment. In selecting the cultivated soils preference should be given to those soils which have not been fertilized within a few years. If recent fertilization has been practiced the character and amount should be noted.

Preparation of Soil and Planting.

The soil when received is given a number, thrown upon the floor, and turned repeatedly until air-dry. It is then passed through a sieve of one-fourth inch mesh and the percentage of stone, sticks, and other material not soil, determined. The sifted portion is thoroughly mixed, quartered, and a sample of from 10 to 20 pounds taken for analytical purposes.

About one-half inch of the soil in the pot is removed and the seeds are placed on the sub-surface thus exposed. The soil removed is then replaced so that the seeds are all covered to a uniform depth which varies somewhat although generally it is about one-half inch as stated. Forty kernels are planted if oats are sown and 20 if peas or beans are planted.

Watering the Soil.

As the planting is completed distilled water in measured

quantities is added to the external water jacket until, by capillary attraction, the surface of the soil shows spots of moisture, but does not become thoroughly saturated. The water is added in such a quantity as to secure the absorption of about 67 per cent. of the total amount which the soil will hold.

The pots are frequently weighed in order to determine the amount of water they hold. They are lifted by means of a differential pulley, as before described, which is fixed on a suspended bar by pulleys which can be pushed from door to door directly over the center of the car. The need of the soil for water is determined by the appearance of the growing crop, by the weight of the pot, and by the appearance of the suface of the soil. The method of weighing is shown in fig. 9.

Even though the Potomac water carries so small an amount of mineral matter it may contain some plant nourishment and, therefore, all of the water used in watering the pots was distilled. This water contains no plant nourishment at all, except a faint trace of ammonia, so small in amount as to be negligible. At first the water was distilled at the Bureau of Chemistry and carried to the pot house on a truck especially prepared for that purpose. Later a still was erected at the pot house and has now been in use for several years. The distilled water is prepared from the steam of an ordinary boiler liquified in an appropriate condenser.

Since the weighing and measuring of the water at each application would be time consuming and troublesome, a device, shown in fig. 10, was used whereby a large number of measured samples could be taken at once. Each of the conical vessels holds exactly two pounds. They are held in frames so that they can be thrust beneath the surface of the distilled water, which is kept in a barrel, and are kept in this position until filled when the frame holding them is lifted out and the water is thus ready for immediate use. This apparatus greatly simplifies the measuring and weighing of the water added to the pots.

The water is applied as late in the afternoon as possible so that it may be absorbed by the soil during the night and with as little loss from evaporation as possible. From time to time during the growing season, in order to ascertain that the whole amount of the soil is moistened, a sufficient quantity of water is added to saturate the soil, and the drainage which escapes in this way is returned from the pan in which it is caught to the regular water jacket of the pot, rendering the loss of fertilizing materials by drainage impossible.

II. RELATION OF THE SOLUBILITY OF POTASH AND PHOSPHORIC ACID IN SOILS TO CROP PRODUCTION.

Description of Soils.

The data here presented are obtained from fifty soils, sixteen of which are virgin types from as many States. The remainder are cultivated types twenty of which represent the arable lands in general cultivation in that number of States, while six of the number being typical of a considerable area commonly known as muck or vegetable soils. The eight remaining samples are from the famous Rothamsted experiment station in England and were secured through the courtesy and under the personal supervision of the late Sir Henry Gilbert.

The virgin soils are numbered from 1 to 16 inclusive; those from 17 to [illegible] inclusive have been cultivated. The letters "a" and "b" are used in the tables to designate the surface soil and subsoil respectively. In a study of soils it is especially important that complete data with reference to the soil in its natural state should be supplied, i.e., the original forest or grass growth, the nature of the crops to which experience has shown them to be best adapted, and the methods of cropping together with the yields.

Soil No. 1 is from California. The sample was taken from the Berkeley University grounds. It is called a virgin soil of the adobe type. The surface soil is the first ten inches and the subsoil the second ten inches. The sample sent to the Department was called black adobe, the black layer being over 30 inches deep underlain by a yellow, stony subsoil. It is described as becoming exceedingly sticky when wet but ploughs easily at the right point of moisture. When ploughed a little too wet it clots heavily but the clots tend to pulverize in drying. With shallow tillage or when left untilled it forms widely gaping cracks in the dry season. If tilled deeply and thoroughly it retains moisture, produces a luxurant growth of weeds throughout the dry season and is almost ashy in its tilth.

The cultivated portion has been in grain for many years and is badly worn.

Soil No. 2 is a virgin soil from Illinois, Marion County, Carrigan Township, Section 27, The sample of surface soil was taken to the depth of 9 inches and the subsoil from 9 to 15 inches.

Soil No. 3 is from Illinois, Champaign County. It is virgin soil and the surface sample was taken down to 12 inches and the subsoil the following 8 inches. The vegetation was Kentucky blue grass. This vicinity represents the most fertile part of the prairie lands in Illinois. The usual crop is corn, the yield being abundant.

Soil No. 4 is a virgin soil from Indiana, Tippecanoe County. The surface soil and subsoil were taken the first and second 9 inches respectively. The forest growth on this soil was maple, oak, hickory, cherry, etc. The cultivated portion has been cropped for 60 years in corn, wheat and clover. The present yield, without fertilization, is about 60 bushels of corn or 30 bushels of wheat, per acre. It is a dark, sandy loam inclined to harden after a rain, but not as clay does. The subsoil is very compact and in general is like the surface soil though lighter in color. This virgin soil is said to have been in blue grass pasture for 20 years and previous to that was under cultivation. It is considered a fine wheat soil, having yielded 40 bushels of wheat under favorable conditions.

Soil No. 5 is a virgin soil from the station farm at Ames, Iowa. The samples are from the first and second 9 inches respectively. The soil is considered of average fertility, rather more open and porous than the usual prairie soil. Corn and oats have been grown on this soil with some timothy and clover. The sample that has been under cultivation represents the stronger soil.

Soil No. 6 is a virgin soil from the college farm at Manhattan, Kansas. The samples were taken to a depth of 6 inches. This is a very fertile soil but it is not entirely representative of the prairie lands of Kansas. The farm may be

described as a second bottom land and more closely resembles the Indian corn lands of the State.

Soil No. 7 is a virgin soil from the station at Amherst, Massachusetts.

Soil No. 8 is from Michigan and is described as originally a soil bearing beech and maple, the land having been cleared about 35 years. It is a sandy loam of glacial origin.

Soil No. 9 is a virgin soil from the station at Columbia, Missouri. The surface sample was taken to a depth of 6 inches and the subsoil through the next 9 inches. The soil in the vicinity from which this sample was taken is described as a tenacious, clay loam having a subsoil of stiff, retentive clay. The depth to limestone is from 20 to 40 feet. The soil is wholly of glacial origin. It is moderately fertile the usual yield being about 25 bushels of Indian corn, per acre. The land was cleared 50 years ago and since that time Indian corn, wheat, oats, clover, timothy and Kentucky blue grass have been grown with the use of little or no artificial fertilizer. The forest growth was white oak, black walnut, elm, hackberry, and sugar maple.

Soil No. 10, from Montana, is a virgin soil taken from the station farm at Bozeman, Gallatin valley. The site of the farm had no forest growth when settled in 1864. The native grasses at that time grew in great abundance. This valley has been recognized as the most fertile one in the Rocky Mountain region. The soil is described as a fertile loam containing a large amount of humus and underlaid by gravel and cobbles. Small plots of oats have yielded crops at the rate of 174 bushels per acre and wheat frequently makes a yield of 60 bushels.

Soil No. 11 is from the station farm at Ithaca, New York. The sample, which is a gravelly loam, was taken from the edge of an adjoining wood and is supposed to have never been ploughed.

Soil No. 12 is from Oregon, a type of the lands of the Willamette valley. It is described as a virgin soil taken to

the depth of three inches, the subsoil having been taken through the following 12 inches. This valley was at one time an inland sea and is now formed largely of the so-called white lands whose fertility is rather low. It was annually burned over by the Indians to make pasture. The little forest growth that exists was principally scrub oak.

Soil No. 13 is from the station farm at Brookings, South Dakota. It is described as a virgin soil the surface sample having been taken to a depth of 15 inches and the subsoil from the following 9 inches. No detailed data are recorded with the sample but it is evidently typical of the very fertile prairie soil in which the State abounds. South Dakota is in the great northwestern wheat belt, the soil of which continues to give good crops under long continued cultivation without the aid of artificial fertilization.

Soil No. 14 is from Texas and was taken from the station farm at College Station. It is called a virgin soil though described as having been in cotton many years ago since which time it has been a pasture covered with sedge and native grasses. The samples were taken through the first and second 9 inches. This type of soil is termed a prairie, post-oak loam, underlaid by a stiff, blue clay subsoil. The usual crops in this vicinity are Indian corn, cotton, sorghum and peas, yielding from 10 to 25 bushels of corn per acre or a bale of cotton from 5 or 6 acres.

Soil No. 15 is a virgin soil from the station farm at Madison, Wisconsin. The surface sample was taken from the first 6 inches and the subsoil through the following 9 inches.

Soil No. 16 is a virgin soil from Pennsylvania. The sample was described as tobacco land.

Soil No. 17 is a cultivated soil from California. The samples were taken through the first and second 10 inches. See soil No. 1.

Soil No. 18 is a cultivated soil from Undine , California. The samples were taken from the first and second 12 inches. No other data are given.

Soil No. 19 is a cultivated soil from Illinois. The surface sample was taken 9 inches deep and the subsoil sample from the following 6 inches. See soil No. 2.

Soil No. 20 is a cultivated soil from an Illinois corn field. The surface sample was taken 12 inches deep and the subsoil through the following 8 inches. See soil No. 3.

Soil No. 21 from Indiana is a cultivated soil. The samples are the first and second 9 inches. See soil No. 4.

Soil No. 22 from Iowa is a cultivated soil. The samples are the first and second 9 inches. See soil No. 5.

Soil No. 23 is a cultivated soil from Kansas. The samples are the first and second 6 inches. See soil No. 6.

Soil No. 24 from Massachusetts is a cultivated soil. See soil No. 7.

Soil No. 25 from Michigan is a cultivated soil. See soil No. 8.

Soil No. 26 from Missouri is a cultivated soil. The samples are the first and second 9 inches. See soil No. 9.

Soil No. 27 is a cultivated soil from Montana. See soil No. 10.

Soil No. 28 is a cultivated soil from the experimental pots of the station at Ithaca, New York. This land has been under cultivation for many years and having been well farmed produces abundant crops. Some of the pots which have been cultivated for 10 years, without fertilization, respond remarkably to tillage. The soil is well adapted to wheat, oats, corn, clover, and potatoes.

Soil No. 29 is a cultivated soil from Oregon. The surface sample was taken 3 inches deep and the subsoil from the following 12 inches. See soil No. 12.

Soil No. 30 is a cultivated soil from South Dakota. The samples are from the first 15 and the following 9 inches. See soil No. 13.

Soil No. 31 from the Texas station is a cultivated soil. It was taken from a cotton field which has not been fertilized and was in sod three years prior to the time of sampling. The

first and second 9 inches were taken. See soil No. 14.

Soil No. 32 is a cultivated soil from Wisconsin. The samples are the first 6 and following 9 inches. See soil No. 15.

Soil No. 33 is from Pennsylvania. See soil No. 16.

Soil No. 34 is a cultivated soil from the station farm at College Park, Maryland. This soil has been in cultivation three or four years after lying fallow for a number of years. Without fertilization it yields about 8 bushels of wheat or 30 bushels of Indian corn per acre. It responds well to fertilization, the yield of wheat running up to 40 bushels. The soil is a light clay loam and seems to be most deficient in phosphate.

Soil No. 35 is from the Department grounds, Washington, D.C.

Soil No. 36 is a composit sample made of virgin soils from Missouri, Michigan, Kansas, and Illinois.

The eight samples following, Nos. 37 to 44 inclusive, are from the famous fields of the Lawes-Gilbert station at Rothamsted, England. (The soil numbers are rearranged in order to place pots in sequence.)

Soil No. 44 is "W 3" of the Rothamsted memoranda. It is from a wheat plot in the Broadbalk field and never has been manured. This field has been continuously cultivated in wheat for 50 years. The average yield after 40 years was nearly 13 bushels per acre.

Soil No. 37 is "W 10 A," a second of the Broadbalk wheat plots. This plot has had an annual application of 400 pounds of ammonium salts since 1844. After 40 years the average yield was 16.5 bushels of wheat per acre.

Soil No. 38 is "W 11," the third of the Broadbalk plots. This plot has had an annual application for 50 years of 400 pounds of ammonium salts and 390 pounds of superphosphate. After 40 years the yield was 21.5 bushels per acre.

Soil No. 40 is "W 13," the fourth of the Broadbalk wheat plots. This plot has had an annual application for 50 years of 400 pounds of ammonium salts, 390 pounds of superphosphate

and 200 pounds of potassium sulphate. After 40 years the yield was 32.5 bushels per acre.

Soil No. 39 is "B 1 A" from a plot in the Hoos barley field, having been in barley continuously since 1852. The plot has had an annual application for 50 years of 200 pounds of ammonium salts. After 45 years the yield was 23 bushels per acre.

Soil No. 41 is "B 2 A," the second of the Hoos field plots. This plot has had an annual application for 50 years of 200 pounds of ammonium salts and 390 pounds of superphosphate. After 45 years the yield was 30 bushels per acre.

Soil No. 42 is "B 3 A," the third of the Hoos field plots, and for 50 years has had an annual application of 200 pounds of ammonium salts, 100 pounds of sulphate of potash, 100 pounds of sulphate of soda, and 100 pounds of sulphate of magnesia. After 45 years the yield was 28 bushels per acre.

Soil No. 43 is "B 4 A," the fourth of the Hoos field plots, has had an annual application for 50 years of 200 pounds of ammonium salts, 200 pounds of sulphate of potash, 100 pounds of sulphate of soda, 100 pounds of sulphate of magnesia and 390 pounds of superphosphate. After 45 years this plot yielded 44 bushels per acre.

The complete data on these 8 soils are given in the memoranda of the field experiments issued by the Rothamsted station.

The four following samples are from Florida, having been taken at Narcoossee, and are typical of the muck lands which are formed by deposits of vegetation, from 80 to 90 per cent. of the so-called soil being organic matter. When cultivated it is generally grown in cane, some sections giving good crops while in others it fails.

Soil No. 45 is described as a virgin soil from the best muck land.

Soil No. 46 is a virgin soil from the poorest muck land.

Soil No. 47 produced a good crop of cane the season before it was sampled.

Soil No. 48 failed to grow cane the same season.

These four Florida samples are so abnormal that they should hardly be classed as soils even though they form a considerable portion of the State. They were used in this series of pot experiments for testing the relative values of the different forms in which phosphoric acid is sold.

Soil No. 49 is from Maryland and was taken from the station farm several years after soil No. 34 was taken.

Soil No. 50 is from Nebraska, and is a typical beet soil sent in by the Norfolk Beet Sugar Co.

The following tables afford a means of identifying these soils:

Tables I and II.

Plan of Experimental Work.

One purpose of these culture studies is to establish an agricultural value for the several soils, if this be possible. It is certainly possible to compare them. The agricultural value of soils is dependent upon climatic influences. Cultures in pots, on soils collected from various localities, eliminate the climatic influence for purposes of comparison. If a soil from the extreme north and one from the south are brought together, under climatic conditions that are suitable for the crop intended to be grown, the difference in yields should be proportionate to the fertility of the two soils.

A soil in Minnesota may be no more adaptable to spring wheat than one in southern Texas. The southern soil taken

to Minnesota might produce spring wheat to the extent of its fertility and the Minnesota soil in Texas would grow cotton. From this point of view it seems that a chemical and mechanical study of soils should be based upon pot culture rather than plot culture. Of course there are many instances in which results can be readily shown in plot culture. In the application of fertilizers, treated and untreated plots adjacent to each other, will present marked differences in yield. But such an experiment is not a study of the soil.so much as it is a study of the fertilizer. The problem of growing crops in the open plot is highly complicated. Even if the temperature and moisture are constant the depth to which the plant may feed is unknown. In pot culture the conditions are simplified to the extent of knowing just how much soil is at the disposal of the plant. Soil investigation may be resolved into three groups: (1) to establish the agricultural value of a soil by its culture in pots; (2) to devise chemical methods that give results most nearly coinciding with those obtained by the crop; (3) to fix a relation between the soil, as to its positive capacity in the pot, and in its natural condition in the field.

It is true that much chemical work has been done on soils without satisfactory results. Many methods have been proposed and one purpose of this work was to test some of these which offer a hope of obtaining definite results of either a positive or negative nature.

Method of Culture.

The general plan adopted was to subject each soil to cereal and leguminous cropping, the oat plant being used as the cereal and the bean for the legume, each being followed by buckwheat, as a second crop every season. This method of experimental culture was applied to the subsoil as well as the surface soil, and was continued unchanged with the exception of the last two years in which the bean was replaced by the cowpea and some

fertilizing experiments were also inaugurated.

In the first year, 1895, clay pots of the ordinary porous type, holding about 14 kilos of soil,were used. During this year the work was somewhat irregular owing to the delay in obtaining the samples. They were potted as they came in, and in addition to the clay pots a few iron ones that were available were used. In subsequent years larger pots were employed, about 25 kilos of soil being used in filling each pot; this weight varied somewhat by reason of the varying specific gravity of the samples, though the volume is constant throughout. In the case of oats 40 seed were planted and after the plants appeared they were thinned to 30. In the buckwheat 30 seed were planted and thinned to 20, and in the beans and peas 25 seed, thinned to 15. This procedure gave a uniform stand.

After seeding, the soils were saturated with distilled water, and distilled water was also used throughout the work. In watering, the cone-shaped can already described was used, the flow ceasing upon the water rising in the tube to the mouth of the can. In some soils the cans were sometimes several hours in emptying.

The pots were weighed each week, and this weight when compared with the dry weight of the pot and soil indicates the quantity of moisture. The method of weighing is shown in the illustration already given. When the crop had reached maturity and just previous to ripening, it was photographed, all photographs being taken on the same scale. When ripe, the crops were harvested even with the surface of the soil, the roots in all cases being left in the pots. Previous to the planting of the buckwheat as the second crop, the soil was taken out, put through a one-fourth inch mesh seive and replaced in the pot.

In the tabulation, the data are arranged under two general heads, namely, virgin soils and cultivated soils. The virgin and cultivated types come from the same locality. Each of these classes is subdivided into two classes, the first one showing the growth of oats, followed by buckwheat and the

second showing the same soils in which beans are grown, followed by buckwheat. Subsequently the data relating to the growth of oats and of beans in the same soils are brought together in an additional table for comparison. After the two general classes of virgin and cultivated soils, a third type known as "muck soil" is tested in a similar manner.

The data secured on each soil include total yields of each crop for every year throughout the period of the experiment. The term "total yield" includes the grain and straw which were not separated. Also in a separate table and arranged in like manner are shown the percentages of nitrogen, potash and phosphoric acid in each crop. From these tables of total yields and percentages, a third form of table is computed, showing the amounts of nitrogen, potash and phosphoric acid removed from the soil by each crop. This table is based upon the weight of the soil in the pot for the year indicated, the weight having varied owing to the removal of some of the soil for analytical purposes. The results are expressed as parts per million, and all data are calculated for analytical purposes to a moisture free basis. For illustration a crop of 60 grams weight containing 3 per cent. of potash (K_2O), has removed 1.8 grams of potash from a pot containing 25 kilos of soil. The potash removed is 0.0072 per cent. of the soil or more simply expressed 72 parts per million.

In tabulating, the data pertaining to the subsoil are always arranged directly under those of the corresponding surface soil. The tables are arranged in the serial order of the soils, the order of the pot numbers being irregular. Thus soil No. 3 is in pots 5, 6, 35, 36. Pots 5 and 6 being surface soil in oats and beans respectively, while 35 and 36 are subsoils of the same planting. After the year 1895, the system of culture was not varied until previous to the planting for 1900. At this time the soils were sterilized because of the belief that in 1898 and 1899 the beans had suffered from a fungus of the species Fusarium as determined by the Division of Vegetable Pathology and through fear that the infection

might spread. The soils in which oats were grown were likewise subjected to sterilization as well as all of the pots and apparatus used in connection with the experiments.

The method of sterilizing employed was as follows: The soils were placed in sheet-iron pans, 6 inches deep, which would hold the contents of a pot. The area of the pan was 20 by 27 inches, and the inside of the pan and cover was painted with a thin coat of asphalt to prevent rusting. The oven used was a chamber having the inner side encircled with steam pipes. The pressure of the steam could be varied at will and the temperature could be brought up to 110° C. The oven would hold 10 such pans as described. The soil was taken from the pot down to the broken stone, put into a pan, covered with a sheet of manila paper and upon this sheet was emptied the stone and that portion of the soil mixed with it.

Some of the soils were in a fairly moist condition when taken from the pots, and where they were too dry, distilled water was used to moisten them as the presence of moisture renders the heat more effective as a sterilizing agent. The soils were subjected to three intermittent heatings, each period of from 4 to 6 hours duration, at a temperature ranging from 90° to 100° C.

Every precaution was taken to prevent subsequent infection, such as having the treated soils removed from any possible contact with the dust of those untreated. The pots and other apparatus used in the work were thoroughly cleansed of adhering soil and each day for three successive days were steamed with live steam for three minutes and afterwards immersed in a solution of 1 part mercurous chlorid to 500 parts of water. The effectiveness of the sterilization on the soil was shown by placing in the oven some potato having upon it a culture of the Fusarium, by which treatment the fungus was destroyed.

Just previous to planting, the soils were inoculated with nitrifying organisms by use of a soil free of fungus. Most of the soil was taken from the pot and mixed with 100 grams of

the inoculating soil, after which it was replaced in the pot and seeded. The soil selected for inoculating use was taken from a clover sod being abundantly covered with root nodules. This sample of soil was put through 1 mm seive and kept in a moist condition to preserve the organism. The results of this sterilizing process, together with those of inoculation, will be discussed later, first as they pertain to efficiency obtained and second with regard to the changes of the solubility of mineral plant foods produced by heating at this temperature for such a period. The sterilization is mentioned here in order that the results for the year 1900 may not be misinterpreted as it induced a marked change in the fertility of the soil. The data for the years 1901 and 1902 include a study of the effects of fertilization.

The tables which follow include, (1) the data of the first year of irregular planting in smaller quantities of soil and in clay pots, with a second crop in but few instances; (2) the data of the next four years in a regular system of growth without interference of any kind, in standard pots; (3) the data of the sixth year including a study of the effects of heating soils; and (4) those of the two remaining years, including a study of fertilization.

Watering Records.

The amount of water used during the growth of each crop has been tabulated in comparison with the weight of the total crop. The watering has been computed to the equivalent of rainfall and recorded as depth in inches. One inch in depth over the area of the pot equals 4.1 pounds. In table No. 30 are recorded the weights of the crops of oats in virgin soils and the total amount of water used to produce them. In table No. 31 similar data for oats in the cultivated soils and table No. 33, those for beans. Corresponding data for oats grown in muck soils are shown in table No. 34.

It is not to be inferred that these crops actually utilized the quantities of water recorded, any more than that the actual

field crop utilizes all the water that falls. In these experiments it was found that from 5 to 15 inches of water evaporate without having gone through the pores of the plant. In some cases where the cropping was a complete failure, as much as 15 inches of water was added. It is evident that the quantity of water thus escaping from a soil, carrying an average of about 70 per cent. of its maximum capacity for water, is much larger than in the field where the content of water is often below this percentage. The evaporation through the surface varies with the nature of the soil and the condition of its surface. To determine the comparative quantities of water escaping through evaporation and transferred through the pores of the plant, four duplicate pots were run as blanks, the soil being kept in a sufficiently moist condition for growing plants, viz., at a little below 70 per cent. of its maximum power to hold water. From these four pots from 13 to 14 inches of water was evaporated during the time of growth for the crop. It must not be forgotten that the foliage of the crop will protect the surface of the soil and materially lessen the evaporation through this source.

(Tables Nos. 30, 31, 32, 33, 34.)

In conjunction with the total amounts of water added, weekly records have been kept of the weights of each pot. From these and the total weight of water added, the evaporation is computed. In table No. 35 some of the data are given, these pots being taken at random merely to illustrate the nature of the records. Complete records are on file, but they are too voluminous to be presented here. In the case of each pot two years have been selected as representing extremes of yield, the years being 1899 and 1900. The first year is one of the smallest crops and the second one of the largest. In addition to the oats and beans grown on the regular soils, data for some of the muck soils are also given. The records of four blanks are shown of soil 34a throughout the experiment, and data for some of the large crops of cowpeas grown in the year

1902 are given for the purpose of showing the excessive evaporation of water taking place through the heavy foliage of these crops. The weight of the crops is given in an adjoining column for convenience in the use of this table.

In some cases an excess of water was added for the purpose of saturating the soil in imitation of the occasional saturating rainfall. Again the soils were allowed to dry more than usual at times in imitation of the occasional drougth in nature. During cloudy days with a saturated atmosphere, the evaporation is practically nothing. The soil might even absorb moisture under such conditions, while one hot day might show the equivalent in evaporation of a week of cool weather. The results are seen in the case of the blank experiments where the evaporation varies from 1 to 6 pounds per week.

While conducting these blanks an experiment was made for the purpose of illustrating the effects of stirring the surface for the conservation of moisture. In the case of the first pair of blanks, pots 174 and 175, the surfaces were pulverized to the depth of about 3 inches. This was done daily when necessary, the surface being kept always in a condition of good tilth. The second pair, pots 176 and 177, were not disturbed in any manner. The results show that where soils are kept nearly at the saturation point the condition of the surface as regards tilth has little effect on the rate of evaporation.

(Table No. 35.)

Photographic Records.

Since the beginning of the work, complete photographic records have been made of every crop grown, making a total of about 2500 photographs. These are made to a uniform scale of one and five-eights inches to a foot. The photographs are taken just as the crop begins its ripening process and prior to any shrinkage in the foliage and are arranged in suitable groups on large sheets of cardboard for convenient reference. They serve admirably as an indisputable check upon any data

given, and while it is not intended that this complete collection will ever be published, with other miscellaneous records they will be available for reference.

A few typical prints are given to serve as an illustration of this record. Photographs of pot 19, an oat crop grown in soil No. 11, are shown for every year from 1896 to 1902. They show a fine yield the first year and a rapid decline in the succeeding years until 1900 when a very abnormal crop occurs and then the yield declines again in the two years following. A bean crop grown in successive years on soil No. 9, pot 17, is also shown. Here the crop diminishes regularly until it all but vanishes in the year 1900 after which it was replaced by cowpeas. Pot 168 shows one of the abnormal crops of the year 1900. The crop weighed 105 grams and produced 1 gram of grain. Pot 76 was another crop of the same year, the crop weight being 90 grams but without seed. Pots 5 and 8 are cowpeas grown in 1902, these being the largest crops grown during these pot experiments.

(Insert photographs here.)

Climatic Data.

In table 35 are tabulated the climatic data for the growing period of each crop, beginning with the year 1896. No data as to rainfall are given as the crops were artificially watered. It is evident that with the same quantity of water some years are more favorable to growth than others. The intensity and distribution of the heat, the hours of sunshine, and the relation of the actinic activity of the sun's rays to the chlorophyll and other cells are all factors in growth. Excessive temperatures followed by many days of cool weather will cause a disturbance of growth. As is seen in the table, the temperature during the growing period ranges from 97° to 26° in one year. During the days of the low temperature the plants were protected in the plant house. Also during the hottest part of the day, during periods of high temperatures, the

plants were under painted glass, though exposed on all sides. They were also protected from high winds.

Influence of Heating Upon the Solubility of Plant Foods.

The yields of the year 1900 show a marked increase over those of the preceding years. The question naturally suggested is, were these yields due to the changes produced by sterilization and subsequent inoculation as previously described? The inoculation at least was ineffective in so far as the nitrifying organisms peculiar to beans are concerned. Two months after planting, the roots of the beans in 12 pots were examined for nodules. In one pot 2 or 3 small nodules were found but in the remaining 11 pots none could be found. The plant upon which nodules were found was in soil 17a. Those examined and found to have no nodules were 1a, 5a, 12a, 20a, 23a, 26a, 32a, and 1b, 5b, 17b, 20b.

The cause of the increased yields is not definitely known. The purpose of the sterilization was to free the soil from a fungus with which it was believed to have been infected. The yields after inoculation were in excess of those for the first year. This led to some investigation of the effect upon solubility of plant foods of heating soils to various temperatures. It is well known that extraordinary yields have been produced on lands from which the forest growth has been burned, much larger crops being obtained than when the lands are cleared by carrying the growth away. This increased yield from burning has been attributed in part to the fertilizing property of the ash which is left upon the soil. This, of course, may have a decided effect but it is no more than probable that heat may have caused increased fertility by its action on colloidial clay or other effect on the solubility of the plant food in the soil.

This theory was subjected to experimental tests. Experiments were made to determine whether the solubility of phos-

phoric acid is increased when soils are subjected to a temperature of from one hundred to two hundred degrees. As a solvent weak hydrochloric acid was used, 5 cc of acid per liter of water, and 200 grams of the soil was digested per liter for 5 hours at 40°C. with constant shaking. These conditions of digestion were used throughout. Five soils were selected, each one from a different state. The determination was first made on soil in a normal condition, second, upon samples which had been heated to 100°C, and third, upon an additional set of samples after heating to 200°C. The results are as follows:

Table No. 26-- Effects of heating on solubility of phosphoric acid.

Sample No.	Parts per million of phosphoric acid dissolved.			
	Normal air-dry	After heating 6 hrs. at 100°C.	After heating 2 weeks at 100°C.	After heating 6 hrs. at 200°C.
1	5	13	55	150
2	7	10	41	52
3	12	18	64	107
4	12	12	31	44
5	34	35	--	74

From these figures it is seen that the effect is variable among soils subjected to the same heating and decidedly variable in the same soil when subjected to different temperatures.or to the same temperatures for different lengths of time. It is evident that phosphates are liberated from the more difficult soluble forms, which indicated that there would be an increase in the supply of this plant food available after heating. This observation is of especial importance in the treatment of soil samples which are intended for study as to the supply of available plant food contained.

The results suggest that some method may be obtained which would have a direct bearing upon greenhouse culture or even intensive gardening, as it would be possible to erect kilns and bake the soil by the cart load, using it as a surface dressing. It has been a practice in greenhouse culture to have the beds warmed by steam pipes embedded in the soil. The supposition

was that the increased growth was due to the warmth of the soil, whereas it may have been partly due to an increased solubility of the plant foods.

The effects of this sterilization were wholly unexpected and they have decidedly changed the plans of the experiment. The soils were so suddenly rejuvinated that virtually the work had to be begun anew. It is of interest to know how lasting the effects of this heating are. Accordingly experiments with a dozen or more of the oat pots have been continued uninterruptedly through the year 1902. In soil 1a the year after the heating, 1901, the yield was very nearly that of the original planting, while the second year afterward the yield was about the equivalent of the second regular planting. In soil 6a the second year after heating, the yield was in excess of that of the regular planting in 1896. This pot seems to continue in its very high yields longer than any other one. Soil 10a decreases in yield rapidly the two following years, the second year showing the minimum yield of the soil. Soils 13a and 15a hold up well in the high yields, while 17a decreases immediately after the first large yield. Soil 22a has a decided increase in the first year after heating over that of the year when heated. To summarize it may be said that the yields in the first year after heating are the equivalent or greater than those of the original planting-- that is before sterilization-- and in many instances the yields even two years after heating are greater still than in the first year of the original culture. The planting of beans was discontinued after the year of sterilization. The extent to which sterilization affected the yield of cowpeas, in the two years in which they were planted is unknown, as no cowpeas were grown under the normal conditions prior to the year 1900. It appears therefore that some soils are decidedly benefitted for at least three years by heating to a temperature of 100°C., while in others the benefit is more fugitive. It should not be forgotten in this connection that heating can in no manner increase the natural stores of plant foods in a soil, but may

easily diminish them by the destruction of organic nitrogenous substances. The practice of burning therefore must, if long continued, result in the impairment of the value of the soil.

The following commentary on the point is made by Ph. Pusly in the Royal Agricultural Society Journal:[a/]

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a/ Vol. II, 1850, p. 377.

> The action of burnt soil rests, I believe, on some distinct principle not hitherto understood. Its effect upon the Oxford clay has been twice brought by me before the Society in this Journal, Vol. VI, p. 478, and more recently, Vol. IX, p. 422. It is quite evident that the action is not a merely mechanical one of opening the soil, but decidedly chemical. The last instance is conclusive on that point: for while four good crops of corn were thereby grown in succession on a cold clay, the ashes were not even mixed with the soil, being merely turned over with the breast-plough. The burning of clay does not answer on all clay soils, but it does answer on most of them, especially on the Oxford clay which crosses England in a wide band; it answers also in Essex, Cambridgeshire, Bedfordshire (Vol. III, p. 323), and in Worcestershire. Mr. Randall's account of the process in Vol. V, p. 113, should especially be consulted by the owners and occupiers of heavy land at the present time. But to return to the theory of burning soil. Mr. Bravender, in the present number, p. 160, states the good effect of the practice of stifle-burning. The most remarkable proof, however, is the circumstance that on peaty soils, and on stone brash soil also, where each heap has been burned, though the ashes have been carefully removed, the utmost luxuriance of vegetation follows on the particular spot, and in contrast sometimes with utter sterility. I cannot but think that the effect is due to the disintegration and decomposition of the soil bringing some of its chemical constituents from a dormant into an active state, and I should think it would well reward a chemist to examine into the whole question of the torrefaction of soils.

Comparison of Total Crops with the Amount of Plant Food Found Therein.

Virgin Soils.

In the virgin soils, the total yield of the oat crops and the following buckwheat crops for each year are tabulated in table No. 3. The variety of oats grown was White-Scotch.

The first examination of the table suggests the inquiry as to how these yields compare with actual field yields. In reply it can be said that a pot is one foot in diameter, corres-

ponding to 0.78 square feet on 1/55452 of an acre. A pot yielding 50 grams corresponds in round numbers to two and three-fourths metric tons per acre.

Noticing first the surface soils, it is seen that the range of yield for the first regular planting is from 20 to 50 grams. More than half of them are above 40 grams and one-fifth are less than 30 grams, showing that the general variation is not large. Considering the crops by years up to the year 1900, with one exception, the yield has been a decreasing one, and in the year 1899 it is from two-thirds to one-fourth that of the first year.

In regard to the subsoils, with the exception of 1-B, 5-B, and 11-B, the results are uniformly low. No. 1-B is an adobe soil, being what is termed a very deep soil, and there is little difference between the first and second 9 inches. Soil No. 5 is likewise a very deep soil. In successive croppings the subsoils are distinctly different from the surface soil in that the yields are not decreasing. But one-third of them drop in the final year, while some few of them actually increase. This is probably due to the subsoil becoming disintegrated. Usually subsoils are compact and seldom stirred so that in them oxidation does not readily take place. But if removed and exposed to the air as is necessary in the various pottings, the tendency should be to release increasing quantities of plant food. It is unquestionably true that cultivation tends to increase the available stores of plant food by exposing the soil to the effects of air, light, warmth, cold and moisture.

The deterioration of the crops from the surface soils, through successive croppings, to which reference has been made, is due to the utilization of the available balance of plant food; that is, they have fed up to the limit of the most deficient element. If in the ordinary course of agriculture, these soils should lie fallow and be exposed to the action of rain and air, the effects of the weathering would be to render more soluble the minerals and so provide a store of plant food

for the next season, provided the rains were not excessive. If after each cropping the weathering conditions should be perfect, it is reasonable to suppose that for a certain period there would be little decrease in the yields. In fact, this is the actual condition where the soil is impoverished through no other source than cropping. In this case, finally the annual supply of available plant food becomes nearly constant, and likewise the magnitude of the crops.

A decrease in yield in field culture as rapidly as that of pot culture would be discouraging. Conversely, this very condition existing in pot culture is advantageous in the study of available plant food. The condition of the effect of weathering being largely eliminated since the pots are kept under shelter during the winter and the soil is under the influence of the crop only, simplifies the work to that extent.

Buckwheat was planted as a second crop, for the reason that it is a crop able to mature in the time which remained for growth. Thus the con ition of the soil can be determined immediately after it has gone through the strain of producing a regular crop,and testing of its utmost producing ability is effected. Also it is a gain of time to obtain the data on two successive crops in the usual period for one.

In table No. 4 the yields of beans are tabulated after the same scheme as that of the oats. The variety planted was Golden Eyed Dwarf. A few of the soils were not planted in beans (Nos. 4, 10, and 11) and these numbers are omitted in the serial order. The yield of surface soil varies from 62 to 20 grams for the first planting in the regular pots. Most of the first crops of beans were in clay pots. The decrease in yields for successive croppings is practically the same as the oats though in some few instances the maximum crop was in the year 1897.

In table No. 5 the yields of oats and beans in the same soil are compared; excepting in some cases during the year 1895 when they were not comparable owing to the difference in the

pots that were in use. In the first cropping about half of the soils are equal in the yields of beans and oats and in the other half the yield of oats is in excess. The fluctuations in the subsoils are about the same in each crop. In table No. 6 the percentage of nitrogen, potash and phosphoric acid in the oats are tabulated and in table No. 7, are given the corresponding data for the beans. In table No. 8 the composition of the oats and beans grown on the same original soils are compared.

It is noticed that the percentage of mineral plant foods in the crop increases as the yields decrease. This indicates that small crops do not permit the most economic utilization of plant foods.

In table No. 9 are tabulated the ratios of the amounts of nitrogen, potash and phosphoric acid removed by the oat crop, to the weight of the soil in the pot, the results being expressed in parts per million. These ratios represent the actual contribution of the soil in potash and phosphoric acid to the crop. It is upon such results that a study of plant food availability must be based with respect to these two substances. Tables of total yield represent the value agriculturally, tables of percentage composition more nearly represent a species value, while tables described as "Parts per million removed" represent the actual quantity of plant food removed from a given weight of soil. Table No. 10 shows the parts per million of nitrogen, potash and phosphoric acid removed by beans. Table No. 11 is a comparison between Nos. 9 and 10. It is seen that in respect of nitrogen beans invariably have a higher content than oats. The potash content of the oats is greater, though not to so great an excess as that of the nitrogen in the beans. In the case of phosphoric acid, with a few decided exceptions, there is a close agreement between the oats and the beans.

Cultivated Soils.

The data for cultivated soils are arranged after the same system as those under virgin soils. Oats and beans followed

by buckwheat were grown each season in duplicate pots. The same irregularities of the years 1895 and 1900 exist as in the virgin soils.

Table No. 12 shows the yield in total crop of oats and the following crop of buckwheat. In the first general planting, the yield of surface soils varies from 65 grams to about 20 grams, excepting one or two very low results. Only three of the results are higher than 50 grams and this figure would more probably represent the maximum yields which are about the same as that of the virgin soils. By years, there is the same decrease of yield, it being slightly greater in the cultivated than in the virgin soils. The yields from the subsoils are generally lower and more irregular than from the virgin soils.

Many so-called "virgin soils" are misnamed. The term "virgin" should probably apply to soil in a primeval state, that is, one from which no plant food has been taken away, but in which the roots of growing plants have extracted from some depth and from the more difficulty soluble forms, mineral matter which is again deposited on the surface, and in a more available form, by decayed vegetation. It is customary however to call soils "virgin," if they have never been actually cultivated. Again, if a soil is continuously used as a pasture land it would not comply with the requirements of a virgin soil. The forage is converted into products which are transported. There are instances, where soils which were originally very fertile have become so impoverished by this treatment that they would no longer serve as pasture.

In table No. 13 is given the yield of total crops of beans. In the first regular planting the maximum crop seems to be about 50 grams or the same as the maximum crop in the virgin soil with oats and beans and the cultivated soil with oats. The yield for the year 1897 seems to be the maximum.

In table No. 14 the yields of total crop of oats and beans are compared in all cases where these crops were grown in

duplicate pots. In the first year the surface soils invariably show a greater yield of oats than of beans while the variation in the subsoils is not so great. In the following years the beans are in excess of the oats in most instances in the surface soils, while in the subsoils they are decidedly in excess. In the two first years of the Rothamsted soils, Nos. 37 and 44, the general yield of beans and oats are very nearly equal, while in the third year the oats make their maximum yield, far exceeding the bean crop which does not fluctuate from the previous croppings.

In table No. 15 the percentage of nitrogen, potash and phosphoric acid in the oats and buckwheat are tabulated. The first year shows the minimum per cent. of nitrogen with a general maximum in the fourth year. In the first regular planting the nitrogen ranges from 1.62 to .73 per cent. Throughout the entire series the nitrogen content ranges from 2.56 to .73 per cent. For potash the results are irregular, having a tendency to reach the maximum in the third regular planting. In the first regular planting the results range from 4.28 to 1.28 per cent. In the entire series there is a range of 6.30 to .76 per cent. of potash. For phosphoric acid the results in the second and third years are higher than those of the first and fourth and rather irregular throughout.

In some cases the percentage of plant foods in the crop seems abnormally high. It is well known, however, that unusual conditions of growth often tend to disturb the normal relations of plant structure. In the growth of sugar beets, for instance, any conditions that tend to reduce the size of the beets also tend to increase its percentage of sugar and mineral ingredients.

The percentage of potash in many of the oat samples in the preceding tables illustrate this tendency. The straw of the oat plant is particularly rich in potash. Wolff, in his tables of ash analysis reports oat straw from field culture with 5.53 per cent. of this ingredient. The analytical data reported were not only proved by duplicate examination but in many instances checked by wholly independent workers. They portray

the marked tendency in pot culture to accentuate the ordinary variations which are found in field culture and thereby acquire an additional scientific value.

(Tables Nos. 15, 16, 17.)

In table No. 16 the percentage results for beans are tabulated. In the first regular planting the range of nitrogen is from 2.05 to 2.72 per cent. The percentages of nitrogen increase regularly after the first year.

In the first regular planting, the potash results range from 3.56 to 1.13 per cent. The phosphoric acid results are very irregular but tend to show an increase in the later years.

In table No. 17 the percentages in oats and beans are compared. The beans show a higher percentage of nitrogen without exception. The potash content of the oats is generally higher, though in some cases, that of the beans is far in excess. During the first year, the oats have a higher content of phosphoric acid, while in the succeeding years the results are very irregular. In table No. 18, the parts per million of nitrogen, potash and phosphoric acid removed by oats are given, while in table No. 20 the results of the two preceding tables are broughttogether for comparison. In this table the results on nitrogen are again very striking, the beans having generally a large excess of this constituent.

Muck (Vegetable) Soils.

The muck soils were treated with fertilizers in the year 1895 as well as the years 1901 and 1902. In consequence this is more a study of the effects of fertilizers than of the virgin soils and the results will be discussed in that portion of the work relating to this subject. The total yields are given in table No. 21. There were four soils and three of them received fertilizers. Phosphoric acid was the only fertilizer used and it was applied in the form of Thomas slag, raw rock and acid rock. The first pot of each series was reserved as a blank, that is, it was cropped without a fertilizer, and in soils 45 and 46 a large increase is shown upon the addition of phosphate in either of the forms. Soil No. 48 shows

no increase in yield from the application of either slag or rock, the yield in the blank being about a maximum. In table No. 22 are given the percentages of nitrogen, potash and phosphoric acid and in table No. 23 the parts per million of the same. In the latter table it will be seen that the results are very high in comparison with those given in similar tables on virgin and cultivated soils. This of course is due to the very low specific gravity of the muck soils, they being about one-fourth the weight of ordinary soils.

Duplicate Croppings.

In addition to the preceding data on the cropping of oats and beans in the virgin and cultivated soils, a number of duplicate croppings have been made throughout the series of years. These duplicates were made when there was a superabundance of the soil sample. The value of duplicate cropping depends upon the thoroughness with which the original samples are mixed and the accuracy of the subsampling.

Assume that a half ton of soil is taken as a sample, representing the upper twelve inches, and the purpose is to make duplicate cropping tests. It is possible that the greater portion of the available plant food may be in the first three inch layer, due to such effects as produced by a prolonged drought, and the remaining nine inches practically deficient. It is evident that a thorough mixing of the total sample is necessary, else the available plant food, which may be confined to the upper layer, will not be equally distributed, and in consequence the duplicates will not have been taken from a homogeneous mass.

Subsequent experience in the detail of this work has shown it to be a difficult matter to render a large bulk of soil homogeneous, and for this reason the duplicate croppings are possibly a study in the subsampling from large bulk samples as well as crop production. As has been explained, this entire soil study is with reference to the sample *en bloc*, and in the

regular series, no quantity of soil greater than a hundred pounds had to be sampled. And further, the only exact relation required in the study was that between the laboratory working sample and its corresponding pot, which could be taken with much accuracy. Therefore, such errors as may exist in the duplicate cropping must not be construed as applying throughout the series of pot experiments which constitutes this study.

In table No. 24 are given the yields of total crops in the duplicate cropping of oats. In some instances the duplicates have rather a wide range. But the single illustration of the duplicate croppings in soil 35a is sufficient to demonstrate the uniformity with which crops may be grown in pot culture. Considering the wide range of the magnitude of the crops, from less than 3 grams up to more than 70, these results can be considered as good duplicates.

In table No. 25 are given the percentages of nitrogen, potash and phosphoric acid in the duplicate croppings of oats and in table No. 26 the parts per million of the same. In the parts per million table, the duplicates in soil No. 35a agree very well, excepting the pot at the head of the series. In the other long series of 35a, with the exception of the potash in one pot, the results are remarkably close. In fact, all the duplicates shown in this table illustrate the frequency with which pot cultures of the same sort show an agreeing cropping value.

In table No. 27 are given the yields of total crops from three soils on which beans were grown in duplicate. The cropping here is by no means so regular as that of the oats. The greatest discrepancy is in the years 1897 and 1898. The per cents. of nitrogen, potash and phosphoric acid are shown in table No. 28, and the parts per million in table No. 29. The results in the parts per million table are the most practical, since they represent the ratio of elements actually supplied.

In soil 34 there are duplicate crops in the first year of 15 and 18 grams. It seems probable that the lower yield would be higher in percentage composition so as to make balanced duplicates in the parts per million removed. In the case of nitrogen, however, the smaller crop removed nearly twice as much as the larger, while the percentages of potash were practically the same, making the variation in parts per million the same as that of the total yields. The phosphoric acid percentages were not in inverse ratio to yield but had a decidedly large direct variation making the variation in the parts per million table much greater than that in the total yields.

In soil 18, the total yields for the first year are very close, being practically 11 and 12 grams. The percentages of nitrogen, potash, and phosphoric acid in the two crops are identical and it might be presumed that the parts per million removed from the soil are identical. There is, however, a decided variation in the latter, owing to the variation of the weight of soil in the pots, namely, about 20 and 17 kilos, relatively.

In soil 49, the duplicates in total yield are about 20 and 16 grams, a decided variation. The percentages of nitrogen, potash and phosphoric acid vary inversely in about the same ratio as the variation in the total yields, and thus the results in the parts per million removed are very nearly the same.

The duplicates in these three soils illustrate very well three conditions. First, small variation in total yields, with large direct and inverse variations in percentage composition, making the results in parts per million removed such that they are not profitably compared. Second, very close duplicates in total yields being perhaps within the limit of error, having nearly the same percentage compositions and a great diversity in parts per million removed. Third, results with a wide range in total yields, but with a percentage com-

position so proportionately inverse as to make the parts per million removed agree closely.

A further study of these tables will show other discrepancies, for which it is difficult to account. Throughout the series of experiments the beans have proved to be an irregularly variable crop. Many times they had to be replanted and only in the third year did they appear to grow normally. This irregularity and other phenomena led to the belief on the part of the pathologists that the soils were infested with a fungus, in consequence of which an elaborate sterilization was made prior to the crop of year 1900. In this year, however, the beans were even more irregular than before, many plantings being complete failures. In the following years 1901 and 1902 the bean was replaced by the cowpea. Owing to the irregularity of the bean cropping and the fact that the oat plant was used on the greater number of soils, the chemical investigation has been applied chiefly to the data from the oat croppings. Further, experience has shown that the general hardiness and feeding capacity of the oat plant render it a favorite for experimental croppings.

SOLUBILITY OF THE PHOSPHOROUS AND POTASSIUM COMPOUNDS OF THE SOIL IN WATER.

In a study of soils with reference to a convenient method for estimating the condition of available plant food, the use of water as a solvent is a natural suggestion, and as a matter of fact, it was made use of nearly half a century since. All mineral matter taken up by the plant must be in a state of solution or of exceedingly fine subdivision, and accordingly must exist in the natural soil extract, or solution, which is held in absorption by the soil in the form of its normal water content. An abnormal flushing of the soil with water will take out in part this natural aqueous extract, and the subsequent determination of its composition will indicate the quantity

of mineral matter extracted in an available state for plant absorption.

In order to determine the quantity of plant food extracted by this method, a series of determinations of the aqueous extract of the Rothamsted soils was made, in which the modern accepted standard methods for the estimation of phosphorous and potassium were employed.

These Rothamsted soils were considered particularly appropriate for this work. In the barley field, the plat B1a has never had an application of any fertilizer, the plat B3a has had continuous application of potash but no phosphate, while B4a has had continuous applications of both, throughout the experiment, extending over half a century.

In the wheat field, there are two plots, W3 and W10, which have had neither phosphate nor potash applied, while W13 has had applications of both throughout the half century. The phosphate has been applied annually at the rate of 400 pounds per acre, and the potash in a corresponding ratio. The history of these plots is given in the Rothamsted Memoranda, and is generally accessible.

(page 61)

The results as given in a table are expressed in parts per million, and pounds per acre foot, at the estimated weight of 3,000,000 pounds of soil per acre.

It will be seen how thoroughly in accord with the conditions of fertilization are the analytical data relating to phosphoric acid. In the four plots where no application of phosphate has been made, the results are uniformly expressed as a "trace," which implies less than one part per million. In the three remaining plots where phosphate has been applied annually, the results are uniform and practically the same, being six, five and five parts per million respectively.

In the potash estimations the results are equally concordant with the conditions of fertilization. The four plots which have never had an application of potash, give six, ten, seven, and five parts respectively, while the remaining plots, fer-

tilized with potash throughout the long series of years, are represented by fifty-two, forty-six and forty-five respectively.

The fertilized plots have practically the same content of phosphate and potash, which is likewise true of the plots which have had no potash applied. This is in harmony with the existing conditions of the fields, the plots are less than 1/2 acre in size, and either adjoining or separated by but one intervening plot, while the barley and wheat fields are adjacent fields of small area, the whole having a quite uniform soil.

These results admit comparison with a study of the drainage waters which are collected by the system of guages in use by the Rothamsted Station. This system consists in collecting the drainage through various depths up to three feet, and over a definite area. The analyses of this extract, which represents a percolation over a period of one year, through a depth of three feet of unfertilized soil, is computed to be less than two pounds per acre of phosphorous pentoxid, equivalent to 0.2 part per million, or, more properly, a trace.

The method of digestion employed is as follows: The soil is thoroughly agitated in distilled water for three minutes and allowed to stand until the greater portion has settled, previous to decantation and filtration. The whole process of stirring and decantation occupies less than half an hour. The filtrate is reduced to a small volume, and the estimations made according to the standard gravimetric method for phosphoric acid.

The study of this aqueous extract was carried further in the case of phosphoric acid. A series of 24 samples, taken from fourteen states as typical of soil conditions, were examined as described above. They represent sand, loam and clay types, as well as combinations of the three. The agricultural value ranged from "poor" up to "very productive."

The solution and estimation were carried on in the same manner as was done with the Rothamsted samples. In one third of

the samples no phosphoric acid was found, and in the remaining two-thirds, the result was in no instance higher than a trace.

The data obtained on the Rothamsted soils are found in the following table:

SOLUBILITY OF THE PHOSPHOROUS AND POTASSIUM COMPOUNDS IN WATER.[a]
(200 Grams of Soil, Stirred in 1000 cc of Distilled Water for 3 Minutes, Stood 20 Minutes, Decanted, and Filtered.)

Rothamsted description Plot No.	Fertilizer	(P_2O_5) Phosphoric acid: Parts per million	Pounds per acre	(K_2O) Potash: Parts per million	Pounds per acre
B1a	.....	Trace	Trace	6	18
B3a	Potash	Trace	Trace	52	166
B4a	Phosphate Potash	6	18	46	138
W3	.....	Trace	Trace	10	30
W10	.....	Trace	Trace	7	21
W11	Phosphate	5	15	5	15
W13	Phosphate Potash	5	15	45	135

[a] Each determination made on an 800 cc solution concentrated to small volume.

Comparison of Methods.

For a comparison of the various methods of dissolving available plant food, ten distinct types of soil have been treated according to five proposed methods of solution and their results compiled in table No. 49. There are also given the quantities of phosphoric acid and potash removed by the crop. The heading "N/5 HCl" implies the method proposed in which this strength of acid was the solvent, and so on with the others. This table would have been more complete had not the supply of samples become so nearly exhausted as to prevent further work. It will be noticed in the potash data that there is a striking similarity of results between the ammonium chlorid method and the fifth normal hydrochloric acid method. It is hardly just to say that, owing to the disagreement of some of these results with those showing the amounts removed by a crop,

they should be looked upon with disfavor. The relation between the available mineral matter in a soil and its actual crop producing ability is not always definite. It may be possible to forecast the amount of mineral matter which will be taken up by the crop, but the ratio of mineral substance in a plant to the organic substance is decidedly irregular. As an illustration, compare soil 40a in the year 1897 with 41a in 1899. The total yields were practically the same, being 39 and 38 grams respectively, while the potash in the first was 6.30 per cent., a wholly abnormal amount, and in the second, but 1.35 per cent., two crops of the same total yields one having five times as much potash as the other. Again, compare soil 39a in 1899 with 41a in 1897. The total yields were 33, and 30 grams respectively, being practically the same, while the percentages of phosphoric acid were 0.31 and 1.44. In the year 1901, soil 1a produced 41 grams of crop with 0.28 per cent. phosphoric acid, and 12a produced a crop of 37 grams, with 1.76 per cent. phosphoric acid. The two latter are nearly the same in total crop yields, while there is 6-1/3 times more phosphoric acid, a quite abnormal variation, in one than the other. Many such illustrations can be pointed out in this series of tables. These variations are indeed exceptional and their occurrence is doubtless due to extreme variations in the relative amount of straw and grain.

General Considerations.

It must be borne in mind that in all of the instances cited the term "total crop" has been used rather than so much seed and so much straw. Of course, the desired crop is seed, and straw is but a by-product of which as little as possible is wanted, though in respect to the fertility of a soil, it is as justly entitled to the credit for its straw yield as for that of its seed. Every one is familiar with the expression "Too much straw," and many crops have not been worth the harvesting, owing to this condition. While such a crop may be a total loss in the agricultural sense, yet it certainly cannot

phoric acid is increasedwhen soilsare subjected to a tempera-

ture of from one hundred r

be attributed to lack of fertility in the soil. There is a remarkable illustration on this point in the yields for the year 1900. An inspection of tables Nos. 3 and 12 show the yields to be abnormal. As has been explained, previous to the planting of this year, the soils were put through a process of sterilization and subsequent reinoculation. The effect of the yields was to make them from 2 to 4 times as great as those of the preceding year, in some cases higher even than the yields of the first year of planting. These crops headed out well and to all general appearances, were full of seed. However, the spikelets while well formed, were either empty or contained very small and imperfect grain. To obtain more accurate data as to these yields of seed, 25 of the larger crops were selected and the grain very carefully separated by hand. The yields of straw and seed are tabulated in table No. 50.

(Table 50.)

If tables Nos. 6 and 15 be examined it is noticed that the percentage composition of the crops for the year 1900 is, with very few exceptions, without marked variation from that of the preceding years, in the case of the same pots. That is to say, no abnormal condition would be indicated by this table. In tables Nos. 9 and 18, which give the actual amounts of mineral matter removed by the crops, the increase is well illustrated. The increased yield in these cases has been an increased amount of crop of the same composition, rather than a decrease in the mineral percentage as would have been expected, from a study of other data recorded in this bulletin.

The ability to produce certain modifications in a plant is one of the weapons of agriculture. The requisites are soil and climate, fertilizers and a knowledge of the laws of variation. Often it is not the quantity of the crop in which one is interested but some specific feature thereof. As an illustration, the sugar beet may be cited. In this case it is not the largest crop that is desired but the greatest amount of a combination of elements which make up the sugar. This Bureau

has shown the sugar beet to be a product of climate rather than of soil.[a/] In most instances, the soil in which these beets are grown would produce a greater tonnage of beets, and very

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a/ U.S.Dept. Agri., Bureau of Chemistry, Bul. Nos. 64, 74 and 78.

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probably of a lower sugar value, were it not that climatic conditions had been selected which produce a maximum yield of sugar, rather than a maximum tonnage. The tobacco plant may likewise be cited, as it illustrates remarkably the effects of climatic conditions on composition and quality. An indigenous plant is nothing more than one in which there is some strong adaptation to the existing conditions of soil and climate. In other words, an indigenous plant is one that may be regarded as having been produced by its environments.

If a soil is deficient in readily available food the plant will starve, even though there is an abundant store just beyond this limit. If this deficiency can be artificially supplied to the extent of the needs of a plant in the tender stages of its growth, it may then be able to feed on the grade just beyond the readily available limit and thus make a crop. This statement serves as an explanation of the fact, that the addition of comparatively small quantities of fertilizers to soils deficient in readily available food, has resulted in the removal of a larger amount of these foods in the crop than was added in the fertilizer.

In table 46 are found data showing gradations in solubility with respect to strength of solvent. Such soils as 3b, 21a, 2a, 23b, 39a, 41a, and 42a are apparently very deficient in available phosphoric acid and to them minimum quantities of phosphoric fertilizer applied as a stimulant would be ineffective. In soils like 30a, 23b, 9a, 11b, 17b, there is a deficiency of phosphoric acid as shown by the weakest solvent, with a rapid increase in the successive solvents of increasing strength. Enough added phosphoric fertilizer to produce a stimulating effect appears to be all that is needed in these

cases. If methods can be developed which will illustrate the different degrees of availability in which plant food exists, the first examination of the soil will be to ascertain if the required plant food is sufficiently abundant in an available state.. If so, that should suffice. If found deficient a second study will determine whether a mere stimulant is needed, or an addition sufficient for the whole needs of the plant. To sum up the conditions which determine whether soils are adapted to certain crops or not, one must consider what is necessary to make the balanced ration for the plant to be grown. Whether commercial values admit of the addition of an artificial food is an important economic point which must be given careful consideration.

In the adaptation of crops to soils there is to be considered the nature of the root system of plants, their ability to penetrate and the depth to which they feed. This in conjunction with the soil, with respect to the nature of the underlying strata or subsoil and the depth to which available plant food exists. Some plants send out an interminable network of thread-like roots which trend toward any especially fertile places in its vicinity. They feed near the surface where the soil offers least resistance and so extensive is the system that they are within an absorbing distance of almost every particle of soil. Some species of plants have a root system made up of tendril-like cords, which are known to extend to a distance of 4 to 6 feet, where they do not meet with too much resistance in the subsoil. It is easy to conceive of soils made up of a friable surface, 4 to 6 inches in depth, resting upon a hard compact subsoil or almost "hardpan," or again of soils of several feet in depth, with no change in physical structure; and of an indefinite series of types between these extremes. Also, soils of a suitable physical structure in which the plant food is confined solely to the topmost layer, or in the topmost layer and diminishing as the depth increases, or generally distributed, making a homogeneous soil in physical

and chemical construction. It is reasonable to say that a soil of the first type with its shallow surface and impenetrable subsoil would be poorly adapted to a plant with a root system of a limited number of cord-like tendrils even though this surface layer should be extremely fertile, whereas a root system of numberless threads could obtain food in abundance.

Nor would a soil of suitable physical condition be adapted to a system of deep feeding roots, if it was shown that the available plant food was totally confined to a few upper inches of soil. This same total amount of available food distributed throughout the same depth would more nearly meet the requirements of the plant with long tendril-like roots, while the hair-like roots of a shallow feeding plant would be unable to obtain sufficient nourishment for a normal growth. To sum up, in selecting the plant that will be best adapted to a given soil, the following points must be considered: Is it a general crop or some specially modified feature of the plant that is desired? What is the predominating element which the soil will be called upon to supply? What is the nature of the root system of the plant? Does it feed in a shallow and concentrated manner or after a deep and distributed fashion? What is the physical condition of the soil? Does it terminate abruptly in a hard under stratum, or is it permeable to a sufficient depth? If it is but a thin layer of soil, is there available food enough to supply the requirements? Or if it is a deep layer, will the available food be at the surface or distributed to some depth? And in all cases, does the proportion of essential foods exist in a ratio somewhat similar to that of the requirements of the plant?

Mechanical Composition of the Soils.

Method.

The mechanical composition of the soils is first presented so as to give an insight into their texture. In obtaining these data the beaker decantation method was modified to some extent. The sample was prepared for work by being passed

through a sieve of 1 mm mesh. The method originally practiced by Osborn was to pestle the saturated soil, using a pestle with rubber tip so as to break down the soil masses into fine particles. This method of pestling admitted of sufficient accuracy only when performed with much care and in addition was very tedious. For this reason a method of agitation while suspended in water was substituted, using a bottle, cylindrical in shape, which is about 6 inches high and 1-1/4 inches in diameter. In this, 20 grams of soil are placed and the bottle filled with water to about two-thirds of its capacity, and stoppered. A frame, constructed to carry a dozen or more such bottles, in the form of a swinging-shaking machine is used and run at the rate of 150 strokes per minute for an hour by use of a motor. Siftings are made as usual and decantations controlled by the microscope down to 0.006 mm. It was concluded that separations below this size as controlled by the microscope, were impracticable and an arbitrary period of floating was adopted consisting of decanting all material that remained suspended for 18 hours, from 4 o'clock in the afternoon until 10 o'clock the next morning. This decantation continued daily, until the water was practically clear, after which the residue was weighed and classified as material below 0.006 mm. in diameter and which would not remain suspended 18 hours. The decanted portion or that which remained suspended was determined by difference.

Results.

The first column of tables Nos. 36 and 37 shows what per cent. of the prepared sample had a greater diameter than .25 mm; the second column what per cent. was less than 0.25 mm and greater than 0.10 mm in size. In the study of such tables as Nos. 36 and 37, the data in the first three columns may be combined to represent the amount of sand and in like manner, the silt and the clay percentages may be united. The experienced agriculturalist can generally see these differences in the proportion of sand present in the field, but the investigator in the laboratory as a rule has no such opportunity.

From the data at hand no constant relation is shown between crop yields, or plant food removed by the crop, and the physical composition of the soil as shown by the mechanical analysis. As an illustration those virgin soils which have been planted in both the crops, oats and beans,-- that is, all of the virgin soils with the exception of Nos. 4, 10, 11-- may be cited. If the average yield of the two crops for four years be taken as a basis, soil No. 5 ranks first and No. 7 is last. There is in this case a marked physical difference between these soils, No. 5 seems to be a uniform mixture of sand, loam and clay while No. 7 is practically nothing but sand. In the case of No. 2 which is last but one in yield and No. 5 are found soils which are very similar mechanically, with the exception of the coarse sand, but the yields are very different. Sample No. 6 ranks medium in yield and when compared with No. 5 shows a decided similarity in mechanical structure.

Chemical Composition of the Soils in [a] Equilibrial Hydrochloric Acid.

Method.

In the chemical analyses of these soils the method used is that suggested by Drs. Owen and Hilgard,[b] or digesting in hydrochloric acid (1.115 sp. gr.) This was varied according to suggestions made by referees on this subject in the Association of Agricultural Chemists.[c] Acid of the above strength

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a/ A solution from which HCl and H_2O begin to distill over. The sp. gr. is 1.115.

b/ Principles and Practice of Agricultural Analyses, Vol I, pp. 345, 356.

c/ Lbid., pp. 345, 353.

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was used but reflux tubes were employed in order that the volume might be kept constant. Flasks of Jena glass, 250 cc capacity.

with ground glass stoppers sealed to reflux tubes, 36 inches long and 3/8 inch inside diameter, were found to be satisfactory. Into the flask 10 grams of soil were placed with the 100 cc of acid. Digestions are always made in this laboratory on the steam bath, live steam being used. The flask is surrounded by the steam only to the depth of the acid. The effect of continuous digestion by this method was studied.

For this work, 6 samples were selected and digested for four periods, namely 1, 5, 10 and 20 hours respectively.

Table 38.

In each of the samples the per cent. of insoluble residue decreased with the continued digestion, there being a difference of about 5 per cent. between 1 and 20 hours. The quantitative increase in solubility is principally in the alumina, the next in the iron. The greatest variation of percentage of solubility was in that of the lime. In two of the soils this was more than doubled and in the others, a decided increase occurred. The sulphates and phosphates alone remained constant. The variation between 10 and 20 hours seems comparatively slight and as ten hours had been in general use, that period was adopted for the subsequent work. The digestions were made on two days, five hours each day, the steam being shut off over night. During digestion the samples were shaken every hour.

In tables 39 and 40 the chemical composition of the virgin and cultivated soils is given. In these as in the other tables, the data for both of the subsoils are placed directly below those of its surface soil.

Tables 39 and 40.

The results for carbon, hydrogen and nitrogen are obtained according the usual official methods of the Association of Official Agricultural Chemists for such work. The methods used for total phosphates and potash are as follows:

The decomposition of the soil is effected by the use of hydrofluoric acid. After two grams of the soil have been ignited

in a platinum dish over a bunsen burner to destroy organic matter, hydrofluoric acid is cautiously added to avoid loss by spurting. The residue is evaporated to dryness on a steam bath, taken up with water and a few drops of hydrochloric acid, filtered, washed, and the filter and contents placed in the dish, and the paper burned. The coarse residue is pestled in an agate mortar, redigested in hydrofluoric acid, and taken up with water and a few drops of hydrochloric acid added as above. This is repeated until the residue is completely decomposed.

In presenting this series of chemical results it is not presumed that each independent result will be capable of interpretation, but rather that the whole will serve as a reference table which may aid in establishing deductions of a positive or negative character. In fact there are many data included in this series of tables which have no apparent individual bearing on the problems under discussion, but the data are given in full that they may be available for study, for other purposes, or for comparison.

Comparison of Crop Yield and Complete Chemical Analysis of the Soil.

Table No. 41 is a collection of data from 34 pots in which oats have been grown and upon the yield of this crop the agricultural value is based. In this table the soils are arranged in cropping rank, the soil of greatest productiveness being first, as shown in the last column. Should the complete chemical analysis be used as a basis for arriving at the fertility of these 34 soils, this first soil would rank thirteenth. Considering the potash, phosphoric acid, nitrogen and lime, it would rank fifth, and so on as indicated in the several columns. These values are obtained as follows: The first soil ranks first in potash as is seen in the tables Nos. 39 and 40, in percentage of lime it ranks tenth, eleventh in phosphoric acid, and sixth in nitrogen, an average rating of seven which compared with the other soils gives it a rank of five. If this

table be divided into halves so that those soils ranking in crop value from 1 to 17 are in the first half, it is seen how many by actual count will rank higher than 17 under each of the column headings.

This summary is shown at the bottom of the table. Opposite the heading "First Half" is given the number of soils found within this division. Under the heading "Theoretical" is given the number that should be found there were the basis of comparison a true one. In like manner the table may be divided into thirds and then into fourths and the number found under each column heading compared with what should be there theoretically.

In addition to this, select from the table the soil that would rank first according to its average standing in apparent fertility from the chemical analysis. This is beyond question soil No. 1 and equally true will soil No. 31 rank lowest. It is rather a remarkable coincidence that in the table these should chance to be adjacent in respect of crop produced. These data show that the probable immediate fertility of the soil under otherwise favorable conditions cannot be safely predicted by the data secured by this method of analysis. Only in case one or more of the essential elements of plant food is found in less quantity than is necessary for crop production could it be said with certainty that the soil is infertile. The fact of the case is that this method of analysis abstracts all the potash and phosphoric acid that would be available over a long series of years and thus shows a far greater quantity of plant food than could possibly be utilized by a single crop. It is necessary, therefore, for the purpose last named, to use a less powerful solvent than that indicated above. The degree of fertility of a soil is due, not to the presence of its millions of pounds of mineral matter, but to its hundreds of pounds, which are in such a condition as to be at once available for the plant.

Compare the first percentage of potash in the table, that

of soil No. 1, with the actual demand of some plant feeding heavily on potash such as the potato. The average crop will require about 120 pounds of potash per acre for its production. Soil No. 1 has 0.554 per cent. of potash soluble in equilibrial acid. The third figure in this result, that is, .004 per cent. is equivalent to 120 pounds per acre to the depth of one foot, or sufficient for the crop for one year. The total quantity 0.554 per cent. will suffice for about 140 years, while the total potash in this sample 1.768 per cent. would grow this sized crop for nearly five centuries, and even then it would have utilized the soil to a depth of but one foot, and the second foot appears to contain a larger percentage than the first.

Estimation of Quickly Available Plant Food.

Method.

The fertility of a soil under favorable climatic conditions is due chiefly to the rediness with which the plant food it contains may be assimilated. The tendency in the crop production is to make greater demands upon the resources of the soil, than nature can meet and when the soil succumbs to the exhaustive strains the deficient element must be rationally supplied. Experiance has shown the necessity for a chemical method which more nearly corresponds to the conditions as found to exist by the growing plant, and since the beginning of this series of pot culture experiments, many efforts have been made to test the methods proposed for determining available plant food. Foremost among these was that of the use of 1 per cent. citric acid as a solvent, proposed by Dyer in 1894.[a/] Later on,

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[a/] J. Chem. Soc., 1894, 65, 115.

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hydrochloric acid of about fifth normal strength was recommended in the Association of Official Agricultural Chemists. In addition to these solvents, work has been done with numerous

others such as ammonium chlorid, ammonium citrate, ammonium oxalate, ammonium hy rate, calcium chloride, oxalic acid, acetic acid, aspartic acid, carbonated water and pure water. Owing to the importance that has been attached to these first two solvents, citric and fifth normal hydrochloric acid, this complete series of soils has been treated according to methods involving their use. The results are tabulated in tables Nos. 42 and 43.

Tables 42 and 43.

The solvent properties of a reagent are so dependent upon the conditions of digestion, that it is essential to ascertain the variations which cause the greatest fluctuation in results. In this laboratory a preliminary study is made of proposed methods before applying them for the double purpose of becoming familiar with their value and, if found reliable, as a check upon the work. In the application of the citric acid method, an examination into the conditions of digestion as used by Dyer was made. These were studied definitely with regard to the time of digestion and volume of solvent. The temperature was recorded as ranging between 10° and 19°C., the work being done in room temperature durin the winter. Other workers in this country have continued this investigation and recorded "room temperature" during summer which is frequently 35°C. This is a range of 9°C., in the original work of Dyer, and 25°C., in the work in the United States. The preliminary work consisted in varying the amount of solvent, the strength of the acid and the temperature of digestion, the length of the digestion being a definite period of 5 hours. The results are tabulated in table 44, 200 grams of the same soil being used in each digestion.

(Table 44.)

The results of the first three digestions are similar, excepting the variations in the amount of solvent used, this varying from 1 to 3 liters. The results on the phosphoric acid and potash are seen to be practically constant. The

second three digestions are like those of the first three except that the strength of acid is doubled. The results on the phosphoric acid and potash are constant in this second three and are the same as those in the first three. In the third three, the conditions are those of the first three except that the temperature is increased 10°C. The results on the phosphoric acid are doubled with no variation in the potash. In the fourth three, the conditions are those of the third three except that the strength of the acid had been doubled. The results are very nearly constant and practically the same as those in the third three. This is to say that variations from 1 to 3 liters of solvent, and a range of from 1 to 2 per cent. acid in strength are without effect upon the results, while an increase of 10° in temperature caused the quantity of phosphoric acid to be doubled.

Without question, the chief controlling factor of solubility in citric acid digestion is temperature. The method as finally used in this laboratory in digesting with citric acid is somewhat different from that proposed by Dyer. The strength of one per cent. is maintained, likewise the use of 200 grams of soil per liter, but the digestion is continued 5 hours at 40°C. with continuous shaking, which is secured by use of a form of shaking, or rather upsetting, device, the whole being enclosed in an oven in such a way that constant temperatures may be maintained. The apparatus is illustrated in fig. 11. It is constructed to hold twelve flasks of one liter capacity. By the use of a small motor the apparatus is made to revolve at the rate of about 50 revolutions per minute. This is just sufficient speed to keep the substance constantly suspended in the liquid, thereby insuring a maximum solvent effect. By use of the thermostat the variations in temperature may be reduced to less than one degree. The temperature of 40°C. is about the lowest that can be artificially maintained throughout all seasons, and this temperature, together with a period of five hourse, have been made part of the definite conditions in the digestion.

Too much emphasis cannot be placed upon the necessity for some definite conditions, whatever temperature and period of time may be found best. It is not unusual to find methods in which the direction is to "shake occasionally." On this point some experiments were made, comparing "shaking once every quarter hour," with continuous shaking, other conditions being the same. In several samples, the results on potash were more than doubled by the continuous shaking. Agitation, therefore, is a very important factor in dissolving the potash in soils by weak solvents.

(Table 45.)

Some preliminary work was done on oxalic acid with reference to its solvent properties. The strength of solvent proposed is 6.3 grams per liter.

The same soil as that used in the citric acid preliminary work was used with oxalic acid. The first series of digestions were made in one liter of solvent for 1, 2, 3, 4, and 5 hours respectively, shaking by hand at intervals of fifteen minutes. The phosphoric acid and potash are constant throughout. In the second series the digestions were made under the same conditions with double the quantity of solvent. The results on phosphoric acid increased with the increased time and are about double those in the first series. The results on potash are constant throughout both series. The controlling factor here is more probably the quantity of the solvent. With every method there is likely to be some one factor, or condition which is more sensitive to variation than others. And if this factor be sufficiently potent it may be used to obtain a series of results of uniform variation. From such a series the result may be selected that corresponds nearest to the object in view. The conditions under which this result is obtained will form the basis for rational investigations.

If citric acid is used as a solvent with fixed conditions of digestion, except as to temperature, the variation caused by this factor should give a series of results in which some

one would coincide with one from a similar series where oxalic acid is used as a solvent, varying only in strength. Or it may be stated more broadly, concordant results can be obtained on any one soil by the use of any number of solvents, provided the conditions in which these solvents are used be varied to secure uniformity. Furthermore, it may be inferred that any desired result may be obtained by the use of any one solvent provided the conditions of its use are varied. Proceeding on the basis that these statements may be accepted as facts, the natural course would be to select a solvent of such a nature that its use would be simple and employ some factor to cause variation in the results which is sensitive and easy to control. Hydrochloric acid conforms well to these conditions.

Having a substance to be digested in a given solvent the conditions to be considered are, strength of the solvent, temperature, length of time and manner of the digestion and the ratio of the amount of solvent to substance. The strength of the solution is an easily varied factor and with the other four fixed, the results may be varied by varying the strength of the solvent. The conditions which remain unchanged in these investigations are temperature 40°C; length of digestion 5 hours; continuous shaking and ratio of substance to solvent, viz. 200 grams per liter.

(Table 46.)

In table 46 there is found a series of results on soils in which all of the conditions of digestion remain unchanged except the strength of solvent. The successive series of data are obtained by diminishing the strength of the solvent one half each time. In order to reduce the solvent action to a uniform basis, a preliminary digestion is made that a correction may be ascertained for the acid utilized by the basic matter in the soil. This feature is one that has been originated and developed in the work of the Association of Official Agricultural Chemists on soils. In this preliminary work 20 grams of soil are digested in 100 cc of N/10 hydrochloric acid for 5 hours at 40°C., with constant shaking. The solution is

filtered and 10 cc of filtrate titrated with a standard solution of N/10 potassium hydrate. Suppose 9 cc of the alkali are required to neutralize the remaining acid. In this case 1 cc of acid was neutralized during the digestion. Then an additional cubic centimeter of N/10 acid must be allowed for, or 10 cc of an unknown strength, must be equivalent to 11 cc of N/10. Therefore 10 cc of N/x must equal 11 cc of N/10 or x equals 9,-- that is, the solvent should be N/9 in order to give a filtrate of N/10. While this deduction is not exactly theoretical, it is within the limits of error in practical work. In such a case an initial strength of N/180 gives a final strength of N/200. The preliminary digestion of each sample will permit of actual digestion in which the strength of the residual acid is approximately N/200 or any other desired content.

Twenty samples of soil were first digested in N/25 hydrochloric acid, corrected for basicity as above. The results on the phosphoric acid vary from 2 to 280 parts per million and on the potash from 76 to 425 parts per million. These and an additional twenty were then digested in acid of one half this strength, N/50 and also of N/100 and N/200 strength, correcting each time for basicity. An examination of table No. 46 will reveal the extreme coefficients of solubility. The phosphoric acid in soil 10a runs with the diminishing strength of solvent from 280 down to 10, While in soil 21a, there is practically no change, an extreme minimum being shown in all cases. Soil 14a has almost a constant quantity of phosphoric acid soluble in all strengths of the reagent. Soil 32a shows the maximum quantity of phosphoric acid soluble in N/200. There is but little change in solubility in acid of eight times that strength. Soil 3a shows practically a constant result in the acids of different strengths, while 1a diminishes about half for each successive strength or in the same ratio as the strength of the solvent. The other data in the table presents many points of interest.

Comparison of Mineral Composition of the Crop with the Estimated Available Plant Foods

In tables 9 and 18 are found the results obtained by the cropping with oats. Those corresponding to the sever l years in which the samples of soil were taken previous to the crop, are tabulated and in addition to the forty studied in table No. 46, twenty more were digested in the N/200 strength. The whole are arranged opposite the crop results for the corresponding year as illustrated in table No. 47.

(Table 47.)

The samples of soil in each case were taken just previous to the planting of the crop. The soil numbers without mark refer to the first planting of that soil. Those numbers with an "a" opposite, refer to the second planting, and those with the "b", the third successive planting. Table No. 47 is not made up from selected data but comprises results of every soil from which a sufficient sample was available for the work.

It may be that the superabundance of one essential food acts as a stimulant causing the plant to become a more greedy feeder on the less available elements. In soil 1a the proportions of available potash and phosphoric acid seem to have been exactly balanced. Almost the same conditions obtain with 8a and 15a. In Nos. 10a, 25a, 11b, 40a and 43a there is seen to be an increase in the phosphate removed by the crop over that removed by the N/200 acid. This may be due to the excessive abundance of readily soluble potash or to some other cause, not evident. In such soils as Nos. 14a, 17a, 32a and 17b more phosphate is apparently available than is utilized by the crops. This may be explained as due to the deficiency of potash. In two of the soils, Nos. 7a and 12a, the available potash seems to have been indicated exactly by the analysis and while abnormally low, the phosphate taken off by the crop very dedidedly exceeded that indicated by the N/200 acid. With the exception of these two instances, the sixty-one comparisons present a most marked illustration of the value of N/200

hydrochloric acid in forecasting the amounts of phosphate and potash available for the growth of oats in pot culture under the conditions described. The comparisons are graphically set forth in fig. 12a.

If this proposed method may be looked upon as a rational approach to a prediction of the amount of available potash and phosphoric acid in soils, it is well to consider very carefully what may not be expected from such analysis. Can this method be applied to crops and soils in general? It undoubtedly applies in general to soils of a normal unfertilized type but its application to all crops is not demonstrated, and it may be said to apply only in so far as the oat plant is representative of general crops.

The term "available" as applied to the plant food in soils is understood to designate that which is in a condition to be assimilated by the plant throughout the season of its growth. Through the process of weathering and of bacterial action additional quantities of plant food are furnished during the period of growth, consisting mostly of available nitrogen which cannot possibly be ascertained in advance. But even in such compounds of phosphorous and potash as exist in the soil, there are in addition to the great mass of forms soluble only in strong solvents, minor portions which are breaking down into more soluble forms and are in various stages of the process. Consequently "available" plant food is that which at the time of planting exists in an assimilable form and in addition, that which will become so during the period of the plant's growth. Furthermore, the stronger the plant becomes the more able it is to feed and if it reaches its maturity in good health it will have utilized plant food that could not have been assimilated under contrary conditions. Therefore, one definition of "availability" is the amount of plant food in a soil which is at the disposal of the plant reaching maturity in a healthy normal state.

The Feeding Power of Different Crops.

The difference in the feeding ability of plants is so marked that any reference to available plant food should be in connection with a specified plant. Again, the period of growth, as above mentioned, is of great consequence. This is dependent upon climate and may be long or short or the growing plant may be either an annual or a perennial.

In table No. 48 are given data showing that oats, barley, wheat, rye, clover, hay and fodder vetches are similar in their feeding power, whereas other crops show a very different capacity. The figures in this table are from crops grown in the field.

(Table 48.)

However elaborately a soil study may be planned, the prosecution of it will develop many new problems. The expansion of any one idea calls for lines of study which are not easily foreseen. It appears essential to begin again the study of some of these problems on broader lines over a narrower field. To connect each series of technical data with practical agriculture is a difficult matter due primarily to the fact that there is no art in which there are so many unsolved problems and uncontrolled conditions as are found in that of agriculture. Of prime importance in the consideration of any analytical method which is intended for practical application, are the questions of time and expense involved in the use of the method. A method for soil analysis for practical application must be cheap and rapid as well as accurate to be of value. In the art of agriculture it is useful to know the conditions of the availability of food just preliminary to planting. This condition varies with the previous condition of the soil and the different crops and methods of cultivation to which it has been subjected. These and the changes of weather conditions render it desirable to know the state which the changing fertility has reached at the latest moment.

Further, the practical agriculturist, will observe, as he

now does, that nearly every field has a different degree of fertility, and accordingly each will require separate study and treatment. Each field may be different also in its contour, exposure to the sun, and degree of erosion. It will not suffice to study one sample of soil as representing a section of so many square miles, nor of one farm, nor even one field. An entire field may be deficient in some plant food, but some parts of it may be less so than others. The farm requires a chemical control just as does any furnace or manufacturing plant whose output is a chemical product. Having this in mind, especial emphasis is directed to the attempt to bring every proposed method to the greatest simplicity in manipulation. It has been found by actual experience in the use of the method as above proposed, that a daily average of ten samples can be easily mantained in the determination of phosphoric acid and potash. The details of the method used are given below:

Details of Proposed Method.

Determine the basicity of the soil by digesting 20 grams with 100 cc of N/10 hydrochloric acid for 5 hours in the shaking machine, titrating the filtrate with standard alkali, using phenolphthalein as an indicator. From the data obtained calculate the quantity of N/10 hydrochloric acid required by 200 grams of soil to give a filtrate of N/200 after digestion, and dilute this quantity to one liter. Place 186 grams of dry soil in a liter digestion flask, partly fill the flask with dilute acid, and shake so as to diplace the air held in the soil, then fill up to the mark. This is the equivalent of 200 grams of soil in one liter of solvent. The 186 grams occupy a volume of 70 cc, leaving 930 cc for the solvent which is in the ratio of 1 : 5. Digest in the apparatus already described for 5 hours at 40°. At the close of the digestion shake the flask well and empty its contents upon a 32 cm fluted filter. Unless the undissolved portion is poured on with the liquid the filter will become clogged. The first part of the

filtrate is generally cloudy, and is poured back until clear. A small filter cone placed in the funnel will prevent the breaking of the larger filter when loaded. These filtrates generally drain through in less than one hour and the volume is found to be very nearly 800 cc.

To 800 cc of the filtrate add 2 or 3 cc of nitric acid and about 10 cc of hydrochloric acid and evaporate to dryness in a porcelain dish of 6 or 8 inches diameter, on the steam or water bath. The nitric and hydrochloric acids destroy the organic matter in the solution and in the end drive off any ammonium chloride which, if present, would subsequently interfere with the determination of potash. Treat the residue in the dish with strong hydrochloric acid, at first slowly to prevent loss by spurting, then evaporate and again treat with hydrochloric acid, until the nitrates have become converted into chlorids, which can be told by the absence of the greenish tinge and fumes upon the further addition of hydrochloric acid to the dry residue. When the conversion is complete, evaporate the acid, cool the dish, add a few drops of hydrochloric acid and about 20 cc of water, and warm until solution is secured. Filter and wash, to remove silica, filtering into a small porcelain dish. This filtrate corresponds to 160 grams of soil and the potash determination is made on the whole of it. Add about 1 cc of the ordinary solution of platinum chlorid and evaporate on the bath according to the usual method for potash, being careful to carry the liquid around the sides of the dish as it becomes concentrated, and to remove just before dryness so as to have the evaporation complete upon the cooling of the dish. This procedure is very necessary and secures a formation of very perfect crystals of the double salt.

To the dish now add about 20 to 30 cc of an acidulated alcohol.[a/] After standing three or four minutes, with an occasional stirring, decant the liquid into a 7 cm filter.

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a/ Jour. Amer. Chem. Soc., 1898, 20; 340.

Wash the salt into the filter with plain 90 per cent. alcohol, as usual, until free of platinum chlorid. Continue washing with the ordinary Lindo solution of ammonium chlorid, 200 grams per liter of water.[a] Wash several times with this or until

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[a] Chem. News, 56; 163.

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there is no more white salt to be seen in the filter, and allow these washings to mix with the previous filtrate. Stir the filtrate and set it aside to allow the ammonium platinum chlorid to settle. Wash the salt on the filter with 90 per cent. alcohol until free of ammonium chlorid, then dry the filter and wash the contents with boiling water through into a previously weighed platinum dish, and after evaporating and drying in a bath at 100° weigh again. After the filtrate above referred to, has stood long enough to settle out, nearly all of the clear liquid can be decanted into a porcelain dish. Use a 6-inch dish to prevent loss by spattering. Then with ordinary alcohol transfer the ammonium platinum chlorid directly to a filter, wash 2 or 3 times and add the washings to decanted liquid in the dish. The little sediment that may have gone over in the decantation can do no harm.

When the alcohol has completely evaporated there will be a large residue of ammonium chlorid present, cover and warm gently, else there will be a violent ebullition of gaseous products.[a]

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[a] Crooks Select Methods in Chemical Analysis, p. 32.

When ebullition has subsided wash off and remove the cover, evaporate to dryness, and add to the cool dish 2 or 3 drops of nitric acid and 10 or 15 cc of water and warm until solution is effected. Wash from the dish with a minimum quantity of water into a beaker of suitable size for the determination of phosphoric acid volumetrically.[a] To this solution add

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[a] U. S. Dept. Agr.,Bureau of Chemistry, Bull. 46, p. 713.

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about 10 grams of ammonium nitrate, let stand in water bath at a temperature of 50°C, until warmed, add about 10 to 15 cc of ordinary molybdate solution, and leave in the bath about 30 minutes with an occasional shaking. Decant through a 9 cm filter, wash the precipitate into the filter, and continue the washing until the filtrate is free of acid by test with phenolphthalein solution. About 200 cc of water are required for this washing. The filter and its contents are returned to the beaker and by use of a stirring rod and a small quantity of water the paper is beaten into a pulp. The titration is made in the usual way with potassium hydrate and hydrochloric acid, using phenolphthalein as the indicator. In this determination the alkali used is one half of the official strength, that is 100 cc neutralize 16.19 cc of normal acid. This makes 1 cc equal 0.0005 grams of phosphoric acid. To express the results in percentage of the soil the weight of the phosphoric acid found, as well as that of the potassium are each divided by 160 grams.

The procedure above outlined obviated dividing the weight of the sample used and adds greatly to the accuracy of the results. Experience has shown that the variation in duplicates when the results are expressed in parts per million is well within that required by good analytical work.

In the development of this study for determining the amount of available phosphoric acid and potash, the complete series of sample was used for the study of phosphoric acid alone. In these determinations the method used was the direct precipitation in the original solution after evaporation to remove silica. The subsequent determination was by titration of the yellow precipitate with standard alkali or what is generally known as the official volumetric method of the Association of Official Agricultural Chemists.[a/] When the work was repeated

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a/ U.S.Dept.Agri., Bureau of Chemistry, Bull. 46.

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for the study of potash the phosphoric acid was again determined in the alcoholic filtrate from the potassium platinum chlorid. These two series of results agreed within the limits of analytical error. Likewise a similar study on pure potassium phosphate gave results very near theory. Such a method of determining the two substances in the same solution is highly advantageous owing to the small quantities found in soil solutions. The above procedure is decidedly shorter than that dependent on the previous removal of the ferric or aluminum phosphate with ammonia, and gives results agreeing well with older standard methods.

Fertilizer Experiments.

(Table 51.)

The first experiments with fertilizers were made on the Florida muck soils in 1895, the first year they were cropped, with reference to the comparative availability of phosphoric acid in raw rock, acid rock and Thomas slag. Table No. 51 illustrates the scheme of fertilization. The phosphoric acid added is expressed as total and available, being computed as parts per million on the weight of the soil in the pot. In the year 1895 the crops were grown in clay pots, but in duplicate, and were subsequently mixed together and placed in one large pot in 1896. Thus the parts per million equivalent is not varied in the years following. The so-called "available phosphoric acid" in the fertilizer is obtained by the prescribed arbitrary method in use in fertilizer analysis;[a/] viz:

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a/ U.S.Dept.Agri., Bureau of Chemistry, Bull. 46, p. 11.

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that soluble im ammonium citrate and water. There was no application of any fertilizer after 1895 prior to that of sodium and potassium phosphate in 1899. Therefore it is possible to study not only the immediate effects, but in addition, the continued effect for 4 years.

The first of each series of soils Nos. 45, 46, 48 and the one pot of 47 are blanks, that is, the soils were not fertilized. Soil No. 45 is considered a type of best virgin soil and No. 46 a poor virgin soil, while No. 47 is a good cultivated one and No. 48 a poor cultivated soil. The data for 1896, the first year of cultivation in the metal pots, afford the most instructive basis for comparison. The cultivated soils are equally productive or superior to the virgin types. The raw rock used is a ground Florida rock, the acid rock being a South Carolina superphosphate. In soils Nos. 45 and 46, the largest yields were obtained from the slag. The comparative effects of the slag are more apparent when the composition of the plant is considered, or the parts per million removed from the soil by the crop. In soil No. 45, the crop treated with raw rock, removed 82 parts of phosphoric acid as against 126 for the slag and 101 for the acid rock; and in soil No. 46 the parts of the same taken off were 103, 117 and 74 respectively.

In each instance the slag pot shows a decidedly increased yield of phosphoric acid. Considering the estimated "available" phosphoric acid in the slag and raw rock, determined according to the method of the Association of American Agricultural Chemists for the estimation of available phosphoric acid in fertilizers, the slag has about one and one half times as much as the raw rock; also in parts per million, the slag crop has removed about one and one half times as much as that grown by the raw rock. This indicates a comparative accuracy as to the estimated availability of the phosphoric acid in these two substances. Comparing the availability of the slag with that of the acid rock the latter is about 1.8 times that of the slag, whereas the slag crop has taken off one and one fourth times as much as that of the acid rock pot.

Applying the same basis of reasoning to soil No. 46, if the availability of the slag be taken as the unit, nine tenths of the obtained available phosphoric acid of the raw rock would be equivalent to the slag which is to say, the method gives to

the raw rock a value too high by one tenth. By a similar comparison of the acid rock with the slag it is estimated that the method should have given but one third of the value shown in the table. Comparing this one third with the two fifths obtained in the previous soil, the small difference of one fifteenth is far within the limit of error in such work as this and they may be said to agree. Likewise the nine tenths as compared with one, are sufficiently near to say that based on two results the slag and raw rock have been comparably valued, while the apparent value of the acid rock is three times too great. As to the correctness with which they have been valued the 160 parts per million of the available slag may be compared with the 126 and 117 parts removed by the crops from the two soils.

In soil No. 48, with the three pots, one blank, one treated with raw rock and one treated with slag, the parts per million removed by the three crops are 190, 182 and , being practically identical. Here it is evident that there was a sufficient available food in the original soil to produce a maximum crop and that added in the form of raw rock and slag was so much in excess.

In the application of fertilizing material the immediate effect and the continued effect are both to be considered. Generally expressed in commercial values it is calculated as available and total on the assumption that the total will become available eventually. The results on these muck soils afford an opportunity for studying the continued efforts of a single application of raw rock, acid rock and slag. Taking the blank in soil No. 45, which is pot 135, and the blank in soil 46 which is pot 139, if the total parts per million be taken, up to the year 1899 the results are 25 and 50 respectively. In soil No. 45, considering that 25 parts per million of phosphoric acid is the capacity when unfertilized, this amount can accordingly be subtracted from the results on the fertilized pots. Therefore the net yield for the raw rock pot for four years is 88 parts of phosphoric acid as against the

corresponding 250 parts for the slag pot and 210 parts for the acid rock pot. As seen in table 51 the total parts per million of phosphoric acid added in the form of raw rock was 550, in the form of slag 360, and in the form of acid rock 300. If the parts removed for four years be expressed as a fractional part of the total phosphoric acid added, it can be stated that a little less than one sixth of that in the raw rock was removed, while two thirds of that of the slag, and two thirds of that in the acid rock was removed by the crops.

Studying soil No. 46 on the same basis, using 50 parts per million of phosphoric acid as the average amount to be deducted for each of the four years, the raw rock supplied 130 parts, the slag 153 parts and the acid rock 117 parts per million of phosphoric acid. The same respective amounts of raw rock, slag and acid rock were added as in soil No. 45. And expressing the parts removed as a fraction of the total added, the results are for the raw rock one fourth, for the slag two fifths, and for the acid rock two fifths. The results for the acid rock and slag in the one soil are equal, while those in the other are likewise equal though about one half that of the first.

As to whether the effects of the added fertilizers ceased at the end of this period, it will be observed in table 23, that in the year 1898 the fertilized pots in each soil did not vary from the blanks, in the amounts of phosphoric acid removed. Therefore, it may be said that the effect of the fertilizers had been practically expended in the three preceding years.

In the year 1899 sodium phosphate was added to some of the pots and potassium phosphate to some others as seen in table 51. The salts were added in a very dilute water solution about three weeks after planting. In the blank pot of soil No. 45, the yields has increased from 7 in 1898 to 11 grams in 1899, and the parts per million of phosphoric acid removed as shown in table 23 is 15, it having increased from 3 in the previous year. In the raw rock pot of the same soil, pot 136,

the parts removed are 17, about the same as in the blank. The same amount of phosphoric acid is practically removed in the four pots of this soil which partially confirms the suggestion that the effects of previous fertilization had disappeared in 1898. Had the remaining part of the fertilizers added in 1898 been partially available, there would have been a greater amount removed in 1899, due to the stimulating effect of the phosphoric acid added that year. It is seen that in the pots 135 and 136, there was no increase in the potash removed, the results for 1898 and 1899 being practically indentical, while the total yield was nearly doubled. Then in pots 137 and 138, where potash was also added in 1899, the potash removed is more than twice that removed in the previous year; the phosphoric acid removed is from 2 to 3 times as great while the total yields only increase from 11 to 14 grams.

In 1901 all pots excepting the three that have been run as blanks were limed. There is only a slight increase in total yields and in some cases the yields remained constant. A more decided difference is seen in the amounts of phosphoric acid and potash removed.

The lime seems to have caused the plant to utilize the phosphate which was previously added without increasing the yield as is seen in pot 137 of soil No. 45. Here the yield for the lime crop was about that of the preceding and unlimed crop, though the phosphoric acid increased from 18 to 28 in parts. In soil No. 46 the yield was considerably increased in pot 140, the potash and phosphate removed being much above the preceding years. In the other pots of this soil the yield fell off after liming. In 1892 raw rock slag and acid phosphate were again applied, the latter being the chemical salt. In soil No. 45 the blank went down to 2 grams in this year, the others being equal or less than the yield of the preceding years though the phosphate removed went up proportionately to the availibility of that added. It will be seen that the slag has a very much greater available supply of phosphoric acid than raw rock, as was observed in the first year, 1895.

Comparing the method as to the availability of the slag and raw rock on the same basis as in 1895, the raw rock should be but one half as available against two fifths as shown in the first year. The results on the use of acid phosphate show to what extent a crop may be over-fed on a single plant food, without increase in the yield of total crop. Pot 138 made one third less yield of total crop where acid phosphate had been applied though the percentage of phosphate in the crop was increased nearly sixfold.. This shows the absence of a proper balance in the rations at the disposal of the plant.

The pots at this period do not serve very well for a study of fertilizers, having been subjected to so great a variety of treatments that it is difficult to separate the results of any new addition from some overlapping influence of a preceding treatment.

Experiments in Plant Feeding.

In the years 1901 and 1902, the growing of beans was discontinued and cowpeas were grown instead. The growing of oats was continued in the same pots as before. In 1902, about 50 of the less valuable pots were withdrawn from this series of investigations and devoted to a new series of experiments.

During these years most of the pots were used in fertilization experiments, with reference to the apparent deficiencies in the soils as indicated by the cropping results. It will be noted that these are experiments in plant feeding rather than a test of fertilizers. The plant food added was in the form of chemical salts available for the plant. No loss by leaching of the soils was possible as in field experiments where heavy rains may carry off much soluble material. In the pot cultures should any water drain through it is poured back.

Oat Plants on Virgin Soils.

In table 52 is given the scheme of plant foods added to virgin soils on which oats have been sown. The salts used

are practically pure. Nitrogen was added in several forms. In 1901, sodium nitrate was used for the first crop and a mixture of equal weights of ammonium chlorid and ammonium sulphate for the second crop, and in two instances for the first. In 1902, only the mixture of ammonium chlorid and sulphate was used. Sulphate of potash and calcium phosphate were used in both years.

The salts were added in the form of a dilute solution. The lime is mixed with the soil before it is potted. In the first year, 1901, the sodium nitrate was added seven weeks after planting, and the other salts about one week after planting. Where ammonium nitrate is used, the nitrogen is given separately as ammonic nitrogen and nitric nitrogen. The salts added are expressed as nitrogen (N), potash (K_2O) and phosphoric acid (P_2O_5) in parts per million of the soil in the pot.

Soil No. 2, a was treated with nitrogen and b with nitrogen and phosphoric acid. Referring to table 46 it is seen that the soil 2a is very deficient in phosphoric acid, having only two parts per million soluble in N/50 hydrochloric acid, but it is abundantly supplied with potash, having 100 parts soluble in N/200 hydrochloric acid. Following the results from this soil in table No. 9, it is seen to be deficient in phosphoric acid from the first year. The phosphate in the subsoil, which had only yielded 15 grams of total crop the first year, has diminished to practically nothing, when the application of phosphoric acid brought the yield up to 40 grams (see table 3), and the phosphoric acid removed by the crop increased from nothing to 13 parts. In the second year, 1902, more phosphoric acid was added, and the phosphate removed continues as in the first year, while the potash removed goes up to 49 parts, though no additional potash has been added. This strengthens the indication of table 46 that potash was abundant in this soil.

Soil No. 3 is treated with phosphoric acid, a in the second year and b in both years. In table 46 this soil is seen to be very low in phosphoric acid in the surface soil and almost deficient in the subsoil, with an abundance of potash in both.

Table 9 shows them to be deficient in phosphoric acid from the first, a being quite low and b containing practically none. In 1901, a, which had no application of phosphate, continued low while b with its application of phosphate only, runs high in phosphoric acid, and abnormally high in potash making a total crop yield of 72 grams, two and a half times the previous best yield in 1900. In the second year where phosphate is applied to each, the total crop yield of a increases nearly 70 grams. The phosphoric acid continues high while the potash begins to descend, owing to the heavy drains upon it. These results strengthen the indications in table 46 that phosphoric acid is needed that the available potash may be utilized.

Soil No. 4 is treated with phosphate in both samples. This soil is not given in table 46 owing to lack of samples, but the cropping results in table 9 show it to have been deficient in phosphoric acid. The addition of phosphate has increased the total crop yield as well as the amount of phosphoric acid taken out by the crop.

Soil No. 5 received an application of lime only on the b soil. Lime is used on most of the samples having an acid reaction, but with this soil, No. 5, the result of lime alone can be seen. In yield of total crops, the limed soil b decreased greatly from the preceding year while the unlimed soil a remained constant and the decrease of potash and phosphoric acid in both from the preceding year was equal, so it may be said that the lime had practically no beneficial effect.

Soil No. 6 had an application of phosphate on the b sample in the first year and the a sample in the second year. Some results are given on 6a in table 46 showing a moderate amount of phosphoric acid present for immediate use, but not much for future requirements, while of potash there seems to be an abundance. The application of phosphate to the b soil brought up its total crop yield to that of the a soil, though primarily the yield of the a sample was about three times that of b. In table 9, it is seen that the phosphoric acid yield has increased together with a large increase in the potash as is shown in table 46.

Soil No. 7 is treated with nitrogen and potash, both samples. In table 46 results are given for phosphoric acid on the a sample showing it to be deficient. The total crop yields are largely increased and it is interesting to note that the phosphoric acid results as given in table 9 show but little soluble, viz., 3 and 4 parts per million. This fact very decidedly strengthens the indications of table 46. Here was a soil, 7a, very deficient in phosphoric acid in the surface sample. The addition of nitrogen and potash did not perceptibly increase the yield of phosphoric acid, though the total crop yields increased to 20 and 25 grams. The potash increased from 4 to 27 in the a sample and from 1 to 28 in the b, while the phosphoric acid increased from about 2 to only 3 and 4.

Soil No. 8 is treated with nitrogen and phosphoric acid. Results on 8a are given in table 46, the indications being that phosphoric acid is present in sufficient quantity for immediate use with no great store for the future, and the same may be said as to the potash, this element being moderately well supplied as shown in the N/200 column. As to the effect of the application of phosphate, the yield of total crop remained constant, the potash removed was identical with that of the previous two years, while the phosphoric acid increased to that of a standard crop. In soil No. 9 phosphate is applied to the b sample only. The increase in the total crop yield is but slight. In the potash as seen in table 9 the yields of the a and b samples are identical and were nearly so in the previous year. This indicates that the application of phosphate did not increase the yield of potash, whereas the phosphoric acid is three times greater in the crop from the fertilized sample. Soil No. 10 has had an application of phosphate and lime in the b sample. The a sample of this soil is extremely fertile, but on the b sample never more than the weakest stand had been obtained. The phosphate increased the total crop yield but it was principally straw.

In soil No. 11 the b sample is treated with nitrogen and lime. The total crop yield increased though the nitrogen and

potash removed remained constant, while the phosphoric acid declined from the high point reached in 1900. In the second year when more nitrogen was added to the b sample the phosphoric acid increased to 16 which is above normal and the potash went up to its highest point. This indicates that phosphoric acid and potash are present in sufficient quantity and that nitrogen is deficient. These indications are borne out by the data in table No. 46 which show the surface soil to be well supplied with both phosphoric acid and potash.

Soil No. 12 has had an application of potash in the b sample, but owing to the very marked effect of the sterilizing treatment in 1900, it is difficult to distinguish as to the result of the added plant food.

The application of a small amount of nitrogen to the b sample of soil No. 13 seems not to have effected the results. Soil No. 14 has nitrogen in the a sample and phosphoric acid in the b. In table 46, No. 14a is seen to have sufficient phosphoric acid for the first crop, but little in store for the years immediately following, and only a moderate amount of potash. Both of these are probably deficient in the a sample at this period and the application of nitrogen makes no increase in the total crop yield or in the potash and phosphoric acid. In the b sample the yield of total crop has always been very low so the potash probably has remained available though not utilized for want of phosphate, as the application of phosphate brings the potash out in abundance.

Soil No. 15 has nitrogen and potash applied on the b sample. In table 46 two results are given on the phosphoric acid in No. 15a. The indications are that phosphoric acid is well supplied for immediate needs and a few years to come, while potash is present in only a moderate sufficiency. The result of adding potash is to greatly increase the crop yield, which also contains a large amount of phosphoric acid, the yield of this constituent, as seen in table 9, has increased to 24, there having been a maximum of only 9 parts in the previous year. This increase in the phosphoric acid is evidence of

its abundance in the soil, and is in harmony with the indications of table 46.

Soil No. 16 has an application of nitrogen and phosphate. There are no data given for this soil in table 46, but it is evident from the results of fertilization that it is abundantly su plied with potash. The total crop yield increased several fold and the potash removed is very high as seen in table 9, having risen from 10 to 64 parts. Had not the potash been sufficient, the yield of total crop would not have materially increased, though the phosphoric acid removed would have perhaps been higher than is shown.

Oat Plants on Cultivated Soils.

Continuing the study of the feeding of oat plants, the results in the cultivated soils are next discussed. The scheme of feeding is illustrated in table 53. Reference is made to table 12 for total crop yields and table 18 for parts per million of nitrogen, potash and phosphoric acid removed.

Soil No. 18 is treated with phosphate and lime on the b sample. The influence of the treatment in 1900 can hardly be distinguished from the effects of crop feeding. The application of phosphate increased the phosphoric acid removed to some extent while the potash remains the same as in 1900. There are no data given for this sample in table 46, but it is probably well supplied with potash while the subsoil is deficient in phosphoric acid.

Soil No. 19 is treated with lime on the a sample and phosphate and lime on the b. The liming of the surface soil was followed by no marked results in either total crop yield or plant food removed while the addition of phosphate to the subsoil brought the yield up to 59 grams. The phosphoric acid removed is also high.

The addition of potash to the b sample in soil No. 20 has not increased the phosphoric acid removed indicating that the soil is deficient in this element which is also the general

indication of previous years.

Soil No. 21 has had an application of phosphate to each sample. The indications in table 46 are that this soil is deficient in phosphoric acid and low in potash. The cropping results on phosphoric acid are conflicting, but the indication of a small amount of soluble potash is confirmed by the crop results. The addition of an abundance of phosphate does not bring the amount of potash removed to more than its average for the preceding years.

Nitrogen and potash were applied to each sample of soil No. 24. The result shows a greatly increased yield of total crop from each sample. No results are given on this soil in table 46 but from the results in table 18 it is evident that the soil had no great store of either potash or phosphoric acid, since after the first two years the parts per million of these substances removed by the solvent are very few. Upon the application of potash and nitrogen the yields of total crop increase eightfold, and the parts of potash removed rise from 5 to 34 while the phosphoric acid increases only from 2 to 4 parts, making the percentage of phosphoric acid in the total crop less than one fourth of the per cent. Without further data than the yield of total crop, this soil is considered as being deficient only in potash and nitrogen as the addition of these foods brought the plant up to so great an increase in total yields of organic matter. But the composition of the crop and its deficiency in seed show the soil to be deficient in soluble phosphate.

Soil No. 25 received an application of phosphoric acid to both samples and of nitrogen also to the b sample. In table 46 some data are given on this soil. It is seen to be low in phosphoric acid with a good supply of potash. The drain of soluble potash on the a sample has been heavy and this element is probably nearly exhausted, but the cropping in the b sample has been light with practically no drain on the potash. So when phosphate is added to the b sample the potash is utilized. The crop removing three or four times the quantity in

parts per million.

The effect of potash on the b sample of soil No. 26 cannot be determined owing to the overshadowing effect of the results of the previous year. Soil No. 27 is recorded as having been treated with phosphate in the b sample. From table 18 it is evident that a mistake in the application has been made, in that potash was used instead of phosphate. Here the potash removed has increased twofold with no practical increase in the phosphoric acid.

Soil No. 30 received an application of phosphate to the b sample, and the result has been to increase the total crop yield about fourfold or to nearly 70 grams while the parts of phosphoric acid removed has increased from 2 to 15. The potash removed has increased to 54 from a previous average of about 22. There is somewhat of a discrepancy here. The results in table 46 indicate this soil to be low in potash, and in no other similar instance is there a result approaching this; that is of the addition of phosphate alone resulting in extra large total crop yield and a large yield of potash from a previously poor one. The fertilization record is at variance with the indications of the available supply.

Soil No. 31 was treated with nitrogen and phosphate in both samples. Here it is seen from the results in table 18 that the nitrogen and phosphate have been correspondingly increased while the potash removed shows no increase. In this sample the phosphoric acid removed is more than three times that of the previous year while the potash is much less.

The effect of nitrogen on the b sample of soil 32 is evidently to stimulate growth so that the amounts of potash and phosphoric acid removed are far above those of former years. The results in table 46 on the a sample of this soil indicate a great abundance of phosphoric acid and a medium supply of potash. The parts removed of potash and phosphoric acid as seen in table 18 tend to confirm these results very strongly, as the potash removed throughout the period of experiment is not above the average, while the phosphoric acid is excessively high.

In soil No. 34 the applic tion of lime has greatly increased the yield of total crop. This soil is from Maryland station where the soils are generally recognized as acid and are greatly improved by liming. These soils are considered dificient in phosphate but fairly well supplied with potash. From table 18 it appears that the total increase in crop yield is principally due to the nitrogen becoming more available. The potash and phosphoric acid are much increased over the former results and continue so the year after liming.

Soil 38 is one of the Rothamsted samples from the plot which had received continuous applic tion of nitrogen and superphosphate for many years. After having been cropped here for four years the pot was again given nitrogen and phosphate. The yields of total crops are not materially effected nor do the results in table 18 appear to show the continued effect of any previous treatment here. It is possible that there is a sufficient supply of these substances resulting from the previous treatment in England.

Soil No. 39 is also from Rothamsted from a plot which had been continuously treated with nitrogen for many years and the application of additional nitrogen which was again made after a four years' interval is without effect.

Soil No. 40, also from Rothamsted, is from a plot which was annually treated for many years with nitrogen, potash and phosphate, and the same substances when again supplied here appear to be without effect on the total crop yields or the amount of plant food removed. The series of Rothamsted soils were fertilized according to the scheme in use for these plots at Rothamsted, sample 44 being continued as a blank, this being the blank plot at Rothamsted. It will be noted in the table of total crop yields that this blank increased in 1900 and descended in 1901 in about the same ratio as that of the fertilized pots and the general result is that these soils were not materially effected by fertilization after the interval of four years during which they received no treatment. The residual amounts of nitrogen, potash and phosphate due to the

previous long applic tion could not be lost by leaching and were of sufficient magnitude to occlude any effects due to the addition of similar plant foods here.

Should the experiments above recorded be repeated the scheme of plant feeding could be advantageously modified in several ways though as it stands now it presents some marked features of great value. Primarily the results of table 46 have been generally supported by the experimental data. When potash is added, and increased yields are secured it is shown that the increase is principally of potash or rather the additional mineral matter is potash. And in like manner the addition of phosphate shows an increase due to the excess of phosphoric acid. The composition of the crop is by no means uniform, and in many instances it is shown that a deduction based upon a total yield of crop would be very misleading. For example it had been customary to conduct plot experiments in which the application of potash is to be made. If the potash plot shows a greatly increased yield over the blank plot, which with difficulty makes a small crop, the supposition has been that such a soil was deficient only in potash. The addition of this substance gives large yields, in consequence of which phosphoric acid is taken from the soil by the plant in much greater quantities. The actual result may be that this soil finally becomes very deficient in phosphate. Similar observations are made with the application of phosphate though as a general rule soils are generally fairly well supplied with potash. But additions of phosphate that increase the yield in total crop do not always increase the amount of potash actually removed from the soil by a previous and very much smaller crop. In like manner the application of nitrogen sometimes increases the yield of total crop while the quantity of potash and phosphoric acid remain constant.

It is also shown that if to those soils in which either potash or phosphoric acid is abundant and the other deficient, and whose yields have been very low owing to the unbalanced condition of the plant food, the deficient element is supplied,

the crop yield is greatly increased, and the yield of the abundant element will increase accordingly.

The use of lime in the growth of oats was with one exception without effect, though there are not many cases in which lime only was applied from which to draw conclusions.

Cowpeas on Virgin Soils.

In the study of the feeding experiments for cowpeas in 1901-1902, the scheme for virgin soils is given in table 55. The yields of total crops are in table 4, the percentage composition in table 7 and the parts per million of potash and phosphoric acid removed in table 10. In table 54 are given the reactions of an aqueous extract of the soil with reference to its condition as to acidity or alkalinity, this examination having been made prior to the preparation of the soils for planting in 1902.

Table 4 shows some very large yields of total crops which, when the scheme of added foods is considered, appear to be due to liming. Through what source the large yields are brought about by the application of lime is very well illustrated in several of the soils. Soil No. 1 has an acid reaction in the a sample and alkaline in the b. The b sample was discontinued in 1902, so the effect of liming is only seen in the a soil. In this sample the yield increased from 100 to 164 grams due to lime only. In table 7 it will be seen that the percentages of nitrogen, potash and phosphoric acid in the crop, having been rather high in the preceding year (1901), become very low. If only the parts per million of potash and phosphoric acid removed are considered, it appears that the limed crop contains considerably less, whereas the total crop is more than 60 per cent. greater than the previous one. The extra supply of potash and phosphoric acid noted in the crop of 1901 was probably made possible by the heating of the soils in 1900.

Soil No. 2 is acid in both samples and failed to make a crop before liming, though phosphate was applied to the b sample,

The second year phosphate and lime were applied and the effect was to increase the yields of total crops from practically nothing to 75.7 and 204.1 grams respectively. The composition of the crop as compared with that of the years previous to 1901 is greatly changed with the exception of phosphoric acid.

Soil No. 3 was fertilized with phosphate in the b sample before liming and both samples treated with phosphate and lime the second year. The a sample scarcely made a crop the first year, so its composition is not considered but the b sample made a crop of 64 grams running abnormally high in phosphoric acid and with a normal percentage of nitrogen and potash. Upon liming, the crop from the a sample increased from 2 to nearly 250 grams and the b sample increased nearly threefold. In composition, the percentage of phosphoric acid is about what it was previous to liming while the potash is but one fourth as great.

Soil No. 5 has one sample, b, limed in the second year. This soil is alkaline in both samples and made good crops without treatment though liming in the second year increases the yield considerably. The composition of the unlimed crop from the b sample is about normal while the effect of liming is to diminish the percentage of potash and phosphoric acid by half, so that the largely increased yield removed no more potash and phosphoric acid from the soil than the former smaller crop.

Soil No. 6 is an acid soil and the effect of lime is to raise the yield of total crop from 2 to 290 grams. In addition to lime, phosphate was applied in the second year and this has kept the percentage of phosphoric acid up so that as much as 43 parts per million are removed by the crop. Also the quantities of nitrogen and potash removed are very high, showing that there must have been an abundance of potash, which is also indicated in table 46.

Soil No. 7 is an acid soil in which the application of lime increased the yield from 2 to 175 grams. The use of potash

without lime was totally ineffective.

Soil No. 8 is alkaline and both samples made good crops without lime though the application of lime increases the yield. The addition of phosphate in the first year brought the amount removed up to the standard, and far above that removed in the preceding years from the same soil, while as in the previous similar instances the potash removed remained constant except in the b sample.

Soil No. 9 was limed both years in the a sample, the second liming increasing the crop eightfold but with a very decided decreases in the percentage of phosphoric acid and potash in the crop.

Soil No. 13 is an alkaline soil and produced a fair crop without lime, but after liming the yield was increased. However, the percentages of potash and phosphoric acid actually removed are less than in the smaller yield, the amount removed being about the average for the previous years.

Soil No. 14 is an acid soil which did not make a crop without lime though after liming, it produced 130 grams. The application of phosphate has kept up the percentage of this substance in the increased yield while the percentage of potash is but one sixth what it was in the former yields. Also the addition of phosphate to the b sample has doubled the phosphoric acid removed with no effect upon the potash.

The b sample, soil No. 15, was treated with potash and phosphate in both years and both samples limed the second year. Both samples show acid reactions though they made good crops without lime. The result of the application of potash and phosphate to the b sample is shown plainly in table No. 10, the amounts removed of these substances having increased about threefold. The use of lime in the second year doubles the total crop yield and the second application of potash and phosphate has kept the yield of these substances up very well.

Soil No. 16 which had no treatment in either year gave a largely increased yield the second year.

Cowpeas on Cultivated Soils.

In the cultivated soils the total crop yields are found in table 13, the percentage composition in table 16 and parts per million removed in table 19. The scheme of fertilization is shown in table 56. In table 54 it will be noticed that about 90 per cent. of the cultivated soils are alkaline, whereas in the virgin soils more than 50 per cent. are acid and an examination of the total yields from the two classes of soils will show the cultivated soils to have been more regular and to have made better yields.

Soil No. 17 was limed the second year and the total crop increased from 109 to 183 grams. But this yield would undoubtedly have fallen in the second year had not lime been applied as the percentage of potash and phosphate had decreased to but one third of what it was in the unlimed year. The largely increased crop removed about two thirds as much potash and phosphoric acid as did the smaller crop.

Soil No. 18 was limed each year in the a sample and the first year only in the b sample, with the addition of phosphate both years to the latter. This soil is acid in the a sample and alkaline in the b and while the a sample was limed in the first year, its yield was greatly increased the second year when it was limed a second time. However, the b sample had almost an equally large increased yield the second year though it was not again limed. While the second liming of the a sample increased the yield fourfold, the increase in potash removed was very small, being only from 68 to 84 parts per million and in phosphoric acid from 16 to 30 parts per million. The b sample, which also received phosphate, showed the same percentage of phosphoric acid in the large sample, while the potash fell to less than one fifth of what it was the first year. The results in the b sample of No. 18 suggest that the large yields of the second year may be due to some other cause than lime.

In the next soil No. 20, neither sample was limed in either year and the yield of the a sample decreased from 95 to 65

grams while the b decreased from 63 to 49 grams and a corresponding decrease took place in the percentage composition of the crops.

In soil No. 23, the b sample made practically no crop, until lime and phosphate were applied when it yielded the very large crop of 235 grams. This soil has an alkaline reaction and just why it failed to make a crop without lime is not obvious. In table 46 the soil is seen to run very high in potash and as anticipated, the large yield has a high percentage of potash.

Soil No. 24 is another example of a soil unlimed in both years to which potash and phosphate were added. In the a sample there was a small increase in yield, by no means to be compared with the increase in other soils on which lime was used.

Soil No. 25, limed in the second year, increased the crop from 60 to 126 grams though with such a dilution of its mineral constituents that the potash and phosphoric acid removed from the soil were practically the same for the two crops.

Soil No. 30 is a negative illustration of the fact that the increased yields of the second year are due to liming. This soil was not limed in either year and in the second year the yield remained constant. Both the crops were large, being 114 and 115 grams respectively.

Soil No. 32 increased in yield upon liming though without lime it made a good crop of 116 grams. In the second year its percentage of potash and phosphate had fallen off about 30 points.

Soil No. 34 made but a small crop the second year though it was limed in both years, the first year's crop being practically a failure.

In the following Rothamsted soils, Nos. 37 to 44, inclusive, the scheme of fertilization is the same as was in use at that station except that no ammonium salt was added to the pots which had previously been planted in beans. None of these soils were limed as in their natural condition they are very basic.

Soil No. 38 which had received applications of phosphate in

England in the second year increased in yield from 73 to 102 grams, but remained constant as to the amount of phosphoric acid removed by the crop. The same is practically true of Nos. 40 and 41 though the latter increased in yield from 59 to 190 grams, the phosphoric acid removed being 11 and 14 parts per million for the two crops respectively. The other soils for some reason, probably imperfect inoculation, failed to make crops in the first year.

The results of the fertilization of cowpeas with potash and phosphoric acid are not especially marked but the effect of liming is predominant. The use of lime increased yields from nothing to several tons of dry matter per acre. The addition of potash and phosphoric acid seems in no marked way to affect the total crop yield though the percentage composition of the crop in respect to these elements is very much changed. Large crops have sometimes removed no more mineral matter than very much smaller ones. If potash and lime are supplied and phosphoric acid is present in small quantities the result is a large crop normally supplied in potash and deficient in percentage of phosphates. If but limited amounts of potash and phosphoric acid are available the unlimed crop will make an ordinary total crop yield. The limed crop will utilize the same amount of these foods and make a much larger yield and the percentage of phosphoric acid and potash in the crop will be much reduced. The large crop also may show no increase over the smaller one in the quantity of nitrogen removed. The increase in weight of crop is therefore chiefly due to carbohydrates. From these results it is apparent that the lime should generally be applied when cowpeas are to be grown, and further that many soils upon which it has been impossible to get a stand of cowpeas, would doubtless grow abundant crops should lime be used. One of the principal benefits derived from cowpeas is the condition in which the soil is left. Its roots in their growth loosen the soil and leave it in a good condition for subsequent tillage. It is also seen that the crop is not a heavy feeder on potash and phosphoric acid and

that large crops have the advantageous effect of increasing the quantity of available nitrogen in the soil both by its roots and by the return to the soil of the manure resulting from the utilization of the crop as a forage product on the farm. It is further seen that applications of potash and phosphate without lime do not increase the total crop yield, though they will increase the percentage composition of the substance in the crop. Consequently there is nothing to gain by fertilizing with potash and phosphoric unless the conditions for nitrification and the growth of the nitrifying organisms on the roots are favorable. Lime does much to secure these favorable conditions.

An interesting observation is that some of the largest yields of peas have been secured from subsoils, in some cases far in excess of those from the surface soils.

Sampling of Soils in the Field.

A great deal has been written on soil sampling with reference to the selection of the place from which the sample should be taken, but the directions for procedure after the spot has been found are limited in number though showing much variety. Practical, common sense is the best guide in the selection of a location for sampling. Any one who wants a sample of soil representative of a definite area would not take it from a fence corner nor from the top of a rotten stump. The spot in the field which he would select would depend upon his powers of observation. The variations in the soils of the field, their location and approximate area, would be known by observing which portions of the field yielded poor, normal or abundant crops. If the field is uneven in contour and has been long under cultivation, it would be suspected that the lower land consisted partly of detritus from the surface of the adjoining hills. If the field is uniform in its crops and contour it will require but little judgment to select a place for taking a sample. If the field varies in well defined areas

each area or similar ones are to be treated as so many different fields. Because a field is uneven in fertility there is no reason for taking a number of samples from different parts of the field, mixing them together and considering the resulting sample as representative of that field. Such a procedure is equivalent to saying that if one half of a field needs 200 pounds of fertilizer per acre while the other half does not need any, the fertilizer should be added to the entire field at the rate of 100 pounds per acre. Some writers have given very detailed directions on this point and their general trend is toward the same conclusion, the sum and substance of which is "Use common sense."

The directions for taking samples, however, are very definite though there are many discrepancies among them. To illustrate this point reference may be made to recognized authorities.[a/]

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a/ Principles and Practice of Agricultural Analysis, Vol. I, p. 65, et seq.

To assume that soils are uniform in compactness and have a uniform weight for a definite volume is to throw a large error into the work at the outset. During the year 1902, 50 samples of soil from twenty-five states were collected by this Bureau. In the directions forwarded for sampling it was instructed that the soil sample represent 4 square feet in area and 9 inches in depth, and the subsoil the next 9 inches in depth. In the 50 samples the weight of the dry soils ranged from 133 to 263 pounds for the first 9 inches and from 154 to 312 pounds for the second 9 inches. This means either that the directions for sampling were not strictly followed or that while two samples of the same size may be secured in different localities in the same manner, yet one may contain a greater weight of material, and a greater quantity of plant food even though the soils may appear to be the same from the analyses.

Considering the results in the first division of table 57 on samples of surface soil taken at various depths, it is seen

that Nos. 1 and 11 are very nearly equal in the content of phosphoric acid which is of medium magnitude; Nos. 2 and 19 are nearly equal in phosphoric acid but of very low value; and Nos. 17 and 29 are exactly equal and of a high value while No. 23 is far above any other sample. Considering the values given for soil and subsoil together, however, quite different relations are discovered. Nos. 1 and 23 are now exactly equal, though as regards the surface soils only, one has practically doubled the value of the other. No. 29 has only half as much phosphoric acid in the soil and subsoil together as has No. 17, though considering the soils alone, they are exactly equal. No. 1, which has slightly less phosphoric acid in the soil than No. 11, has about 34 per cent. more when both soil and subsoil are considered. It is very evident that a study of these soils from these two standpoints would result in very different deductions even though they had been sampled uniformly. These samples represent actual conditions in the field.

The depths to which the samples are taken are given in the second column, and are so varied as to admit only of limited comparison. An attempt is made in the second division of the table to illustrate what would have been the variation in the soils had they been sampled to a uniform depth. The results are calculated to what they presumably would be had the soil and subsoils been sampled to depths of the first and second 6 inches. The method of calculation is somewhat hypothetical but is sufficiently rational to approximate the real conditions. The calculated data for soil No. 3 are illustrated in the accompanying diagram.

(Fig. No. 12.)

AB and CD are the axes. If the surface soil has an average of five parts per million of phosphoric acid in a sample taken to the depth of 12 inches, and the number of parts per million diminishes regularly throughout this depth, it is reasonable to infer that half way between the surface and the twelve-inch stratum there is a layer which contains five parts

per million. Accordingly the ordinate 6 and the abscissa 5 establish the point. The sample taken between 12 and 20 inches has an average of 1 part per million and half way between these points or at a depth of 16 inches from the surface a layer containing 1 part per million may be supposed to exist. So the ordinate 16 and the abscissa 1 establish the point Y, and a line drawn through XY would represent the rate of diminution of solubility as the depth increases.

In order to find the average solubility for a depth of 6 inches, it is assumed, as above, that the average would be half way between 1 and 6, which gives 3 as the ordinate. And the point X^1 where 3 intersects the line XY would give the measure of the abscissa, which is found to be 6. Consequently 6 would be taken as the number of parts per million in a sample taken to a depth of 6 inches. In like manner the average layer for the second 6 inches would be half way between these limits or 9 inches from the surface, which gives the point g^1 or 4 for the corresponding abscissa.

It is of course true that had more points than X and Y been given, or had the solubility for a series to the depth of 20 inches been known, the line of solubility XY would have probably been a curve. But such a curve would be as apt to bend to the right as the left of this line at the points X and Y and in neither case would the diversion be very great, therefore the straight line is a fair approximation.

This hypothesis does not imply that in such soils as Nos. 1 and 17 there would be a line of solubility running parallel with the vertical axis and that the available plant food extends to infinite depths. In these two samples the surface soils and subsoils are homogeneous mixtures, as far as the distribution of available phosphoric acid is concerned, to the depth of more than 20 inches. Calculations for the potash are obtained in a similar manner except that the abscissas are on one fifth the scale of the ordinates.

If it be granted that this reasoning is correct the results obtained in the second division of table 57 may be compared as

was done in the case of the first division. Soil No. 11 is found to be superior to No. 29 in content of phosphoric acid, both as regards the surface soils and the soils and subsoils together, although in the first division of the table No. 29 is superior in both cases. The surface soil of No. 11 is 5 points superior to that of No. 1 while in the first division it was only 2 points greater. Taking the subsoil in conjunction with the surface soil No. 11 is the equal of No. 1, whereas in the first division it had only two thirds the value of that sample. The aspect of No. 3 is most decidedly changed in the second division and its value nearly doubled while the proportions in No. 29 are altered but with practically no change in total value. Nos. 2 and 19 are very low in both cases and No. 23 having been taken to a uniform depth in both instances is constant. Similar observations might be made in regard to the potash but as the figures for the phosphoric acid are smaller the illustration is more apparent when the results on the latter are used. From this table, it is evident that sampling to various depths within the limits shown will result in variable conclusions.

Suppose the method of sampling be uniform in respect of the depth and that samples are taken to successive depths of 6 inches, the manner in which such a sample is taken may influence the result to a considerable extent. The directions for sampling given by the Association of Official Agricultural Chemists, are to "remove two or three pounds of the soil." Such a direction would admit of the use of an ordinary spade in the usual manner. Suppose this was done in the case of soil No. 23, which was actually samples to the uniform depth adopted as hypothetical. A man of average height intending to take out about 25 pounds with a spade would probably mark out an area covering approximately one square foot and on one side of this area he might insert his spade at an angle of 30° from the perpendicular and assume that the three remaining sides were perpendicular. It is obvious that this would take more of the upper half of the 6 inches, than of the lower half

and by a calculation based on the line of diminishing solubility as given in the diagram, the available phosphoric acid in the field from which this sample was taken would be increased from 31 to 32 parts per million. Had two sides been slanted in the same degree, the result would have been 34, while if the four sides had been slanted similarly, the result would have been 37, as against 31, if all four sides were perpendicular. The illustration would be even more marked in such a soil as No. 29 in which the soluble phosphoric acid is confined to the first three inches.

By the foregoing data it has been demonstrated that in sampling a soil, the weight or degree of compactness to definite depths can not be considered uniform, the variation within normal conditions being sufficient to double the estimated weight of the soil in some cases. The variations within reasonably prescribed depths may affect the results in extreme cases by 75 per cent. of their value. The possible variation in methods of taking the same sample, to a fixed depth, may make the result 20 per cent. greater or less than its theoretical value.

To fix a depth through which a sample of soil is to be taken is about the same as attempting to fix a depth through which a plant shall feed. It is more than probable that available plant food does not generally exist at a very great depth, unless transplanted by the movement of water, though in cases of alluvial deposits, or adobe soils, as the two soils from California, Nos. 1 and 17, the depths to which soluble plant food exists may be much extended.

If accuracy is the only factor to be considered in the study of sampling, it is simple enough to take successive depths of 3 or even 2 inches, the total depth being beyond the point where the plant could possibly feed, and make a determination of soluble plant food in each sample. The data on a series of 20 or 30 such samples would probably in most cases give a curve of diminishing solubility, which might or might not vary appreciably from the straight line obtained from joining the two extreme points. Such a series of determinations, however,

would make an extensive soil study impracticable and would not justify the end. Samples from two successive depths should certainly suffice, and if possible, one sample should be made to serve for the deduction of a rational conclusion. An analysis of a sample properly secured furnishes data for the calculation of the amount of soluble food over a definite area and to the depth through which the plant chiefly feeds.

If such soil as No. 1 is to be sampled and a frame enclosing a definite area, say 1 square foot, is used after the method of the Rothamsted station, a single sample to the depth of 18 inches being taken, what data are obtainable? This soil is a homogeneous mixture as far as the content of phosphoric acid is concerned, so the result of the analysis would still be 16 parts per million, which for 100 pounds would be 0.0016 pounds of available phosphoric acid in an area of one square foot or about 70 pounds per acre. Or if the sample had been taken to a depth of 24 inches, without diminishing value of phosphoric acid, there would be 93 pounds per acre, while for a plant which could not feed deeper than 6 inches there would be but 23 pounds available.

Suppose that a soil typical of the other extreme be taken, as soil No. 23, in which the first 6 inches is very rich, while below this depth practically no phosphoric acid is found. If this soil had been sampled as above, that is to 18 inches, and it is assumed that the three successive layers, each 6 inches deep, are of equal weight, then the average number of parts per million would be about 10, which in 100 pounds, as in the preceding calculation, would amount to 43 pounds per acre. Had the depth been 24 inches, or four six-inch layers of equal weight, the average number of parts per million would be 7-1/2 and as the weight of the sample would be increased to 133-1/2 pounds, there would be in the area of one square foot 0.001 pounds or 43 pounds per acre, as in the previous case. If the sample had been taken to but six inches in depth, it would have contained 31 parts per million as given and the weight of the sample over 1 square foot would be but 33-1/3 pounds, on the

basis of the previous estimates, which is the same as 0.001 pounds per square foot or 43 pounds per acre. In this soil, samples taken to depths ranging from 6 inches to 6 feet would in no way affect the calculations of available phosphoric acid in pounds per acre, provided the sample represented a definite area and a definite portion of the thoroughly mixed total sample had been taken for analysis.

As one illustration shows that increasing the depth of sample increases the calculated supply, over a given area, and the other example shows that it does not increase that supply over a given area, the conclusion is that the sample must be taken through the depth to which the intended crop is known to feed. If this depth should be greater than that to which the plant food exists the results will be the same as had the sample been taken only to the depth of the plant food. If the plant food extends to a depth beyond that through which the sample is taken this extra supply being beyond the feeding range of the intended plant, the conclusion would be invalidated were it taken into account in the estimation of the available supply for the crop.

The error involved in the subsampling of a large sample is sufficient to neutralize much of the advantage obtained from the taking of a large area. The same error effects the taking of several samples which are to be mixed as one. Soils such as Nos. 23 and 29 are far from being homogeneous, and the greatestcare would be required in the mixing and subsampling of large quantities. A sample like No. 29 is the equivalent of 1 part of a very rich material and 5 parts of a neutral mass combined to make a homogeneous mixture, and to mix 100 pounds or more so that a subsample of 1 pound would be accurate requires much care.

The latter samples secured for this Bureau, were taken as already stated over an area of 4 square feet and to a depth of 18 inches. These samples, when air dried, weighed over 400 pounds. Where numerous small samples from so large a quantity are desired as was the case in these later investigations, it

is important that the subsamples be truly representative of the whole mass. This homogeneity is best secured by the sampling machine devised in this Bureau and shown in fig. 13. This machine is almost 4 feet high and 8 inches in diameter, and consists of an enclosed vertical shaft to which are attached three disks. This shaft and the disks are revolved by belt connection with a pulley, and as the material leaves the hopper it falls on the center of the upper disk and is radially distributed, passing off the disk in concentric rings, and falling over the second hopper, which is quartered by vertical walls in such a way that opposite quarters of the soil are discarded and the remaining quarters come together as they pass out of the second hopper to the center of the second revolving disk. This process is repeated three times. The operation takes out a sample, one eight of the original bulk which is again put through the machine until reduced to the desired size. The process is one of repeated mixing and quartering so that there is no occasion for a previous mixing of the bulk sample.

The treatment of the bulk sample after it is taken from the field and of the subsample after it reaches the laboratory calls for consideration. As far as possible all stones should be discarded and not reckoned in the weight of the bulk sample, as to give this additional weight to the bulk sample which is discarded in the subsample, introduces an error corresponding to the amount of stone or large pebbles present. The methods of drying samples vary from rendering the soil throoughly air dry under a shed to drying in an oven at a temperature of 40°C. Our experiments have led to the belief that soil is a very delicately constructed substance, in which the physical and chemical properties are changed by very slight influences. Such marked effects as result from the heating of soils to 100° C. should induce caution in the drying of samples in an oven at 40° C. or even at the temperature of an over-heated room. To imitate nature and leave a normal amount of moisture in the sample, and not subject it to an excessive temperature is more

rational. This does not apply to the complete drying of a small sample at 100° C. to determine the amount of moisture in the air dry mass.

In the preparation of the subsample, it is put through sieves ranging from 0.5 mm to more than 2 mm in mesh, the soil being rubbed with a rubber-tipped pestle to avoid crushing particles of gravel. In this Bureau the bulk sample is put through a sieve of one fourth inch mesh and weighed, stones not passing the sieve being discarded. The bulk sample is then put through the sampling machine and reduced to the size wanted. This subsample is put through a 2 mm sieve, and if there is any appreciable quantity which does not pass this mesh, it is weighed and calculated back to the bulk sample, from which its weight is then deducted. This leaves the subsample as a representative of the bulk sample, as if it had been put through a 2 mm sieve. The object of reducing the lumps to so finely divided a state as to pass through the 0.5 mm or the 1 mm mesh is to secure more accurate portions for weighing from the subsample, and also to more closely separate the fine earth from the gravel and coarse sand. For weights of 2 or 3 grams, the finer the soil the better, but in weights of from 100 to 200 grams a 2 mm mesh is sufficiently accurate. The presence of gravel and coarse sand can entail no error inasmuch as it is reckoned in the weight of the bulk sample, and the action of weak solvents on such material can be no greater than that of the plants which the solvent is intended to represent.

In practical work, this Bureau takes a sample over an area 6 inches square two or more successive depths of 6 inches each being taken. This makes packages of about 10 pounds weight. This sample is about that recommended by the Royal Agricultural Society and while it is not so accurate as the Rothamsted method, it avoids the necessity of mixing and subsampling in the field, which would be necessary if samples of 100 pounds or more in weight are to be handled.

A very serviceable instrument for taking samples of this size can be made from 7-inch steel pipe. This pipe has 1/4-inch walls and can be turned down to 1/16 inch thickness, leaving the full thickness for a distance of 1/2 inch at one end for strength, while on the other end a cutting edge is turned. This instrument encloses a definite area which may be computed from the diameter.

III. STUDIES OF THE NITRIFYING PROPERTIES OF SOILS.

INTRODUCTION.

Sources of Soil Fertility.

It has already been stated that no criterion of fertility can be supplied to a soil which leaves out of consideration the number and activity of the nitrifying ferments therein. Extensive investigations have been conducted to determine the nature of the nitrifying organisms and the ones governing their activity. In so far as can be discovered, however, no attempt has ever been made in soil analysis, previous to the planning of this work in 1894, to determine the comparative activity of the nitrifying ferments contained in arable soil. It is especially with this object in view that the investigations reported in the following pages were undertaken.

With the exception of the small quantities of nitric acid and ammonia added to the soil directly by rain water, the whole of this supply is derived from the products of the oxidation of nitrogenous bodies. These products are either stored up as the result of past nitrification or are formed synchronously with their consumption by the growing plant. Nitrogenous compounds are present in the soil principally as organic vegetable or animal remains. All vegetable and animal material deposited in or on the soil contains more or less of these proteid or nitrogenous matters while the amount of nitric acid supplied in this way is represented entirely by the quantity in the organism of the plant or animal unassimilated at the time of its death. In other words it is not demonstrated that nitrates or nitrites are in any sense a product of plant growth. On the other hand animal organisms do not in any sense assimilate nitric nitrogen. Plants and animals thus present an antithesis, the one living on oxidized, and the other on organic, nitrogen.

The quantity of nitrogen which most plants can deliver to the soil is no greater than the sum of organic and nitric nitrogen supplied in their food and they can therefore be re-

garded only as the carriers, modifiers and conservers of this substance. On the other hand, there are some plants, notably those belonging to the leguminous family which permit of the development on their roots of colonies of bacteria which have the faculty of rendering atmospheric nitrogen available for plant growth. Whether or not there exist bacteria other than the microorganisms mentioned which are capable of directly oxidizing and fixing atmospheric nitrogen is still an unanswered question. It is not probable, however, that the difficult task of oxidizing atmospheric or free nitrogen would be accomplished in nature in only one way. In fact it has already been foreshadowed that organisms do exist which are capable of oxidizing free nitrogen in a manner wholly independent of other plant life and producing weighable quantities of nitric acid when developed in media of mineral matters and pure carbohydrates to which free nitrogen has access. It is, therefore, fair to assume that the fixation of free nitrogen is a function of chemical activity quite independent of ordinary plant life and that the leguminous plants take no further part in this process than that of providing in their radical development a favorable nidus for the growth of the nitrifying organism.

By the action of the denitrifying organisms a portion of the nitrogen of nitric acid is constantly being restored to a free state, a far larger portion, perhaps, than is fixed in the atmosphere itself by the action of electricity. Were it not, therefore, for the activity of the nitrifying ferments above mentioned, the stores of nitrogen available for growing plants would constantly become less. Instead of this being the case, however, it is probable that the contrary is true and that, by a wise system of agriculture, the total nitrogen at the disposal of plants may become greater and greater in quantity.

Conditions Necessary for Nitrification.

In order to properly understand the reasons for many of the steps in investigating a soil for nitrifying organisms, it will

be useful to state the general conditions on which nitrification depends.

The nitrifying organisms, like every other one, first of all feels the necessity for food. In general, food which is given to microbes of all kinds consists of some organic matter together with the addition of mineral substances necessary to growth. These substances in general are phosphoric acid, potash, and lime. Of these articles of bacterial food phosphoric acid seems to be the most important. With the nitrifying organisms, however, it has been found that the organic matter can be omitted. In fact, as will be seen further on, the omission of organic matter supplies the best condition for the proper isolation of the organisms.[a/] In other words some forms of the nitrifying organisms have the property of subsisting wholly on mineral substances, i.e., are true vegetables.

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a/ Principles and Practice of Agricultural Analysis, Vol. I, pp. 459 et seq.

The presence of oxygen is also necessary to the growth of the common nitro-organisms. In an atmosphere deprived of oxygen or in which oxygen is reduced to a very low percentage, the process of nitrification is retarded or stopped as the oxygen diminishes or disappears.

The presence of a base with which the nitrous or nitric acid formed may unite is also essential to the proper conduct of the process. For this reason the nitrification should take place in a solution which is feebly alkaline or in the presence of a base which can be easily decomposed so that acidity cannot be established. Calcium carbonate is a base well suited to favor the nitrifying process and its presence in a soil favors the rapid oxidation of proteid matter. The mistake must not be made, however, of supposing that an excess of alkali would favor nitrification. The contrary is true. A slight excess of alkali may prevent nitrification altogether when it is due to the common organisms present in an arable soil. It may be

that in soils charged with alkali a different kind of organism exists which is capable of exercising its functions when the alkali is in excess.

The temperature to which the nitrifying body is subjected is also a matter of importance. The nitrifying organisms have the property of remaining active at lower temperatures than most bodies of this class. On the contrary their action is retarded and destroyed by high temperatures. The most favorable temperature for nitrification is about that of bloodheat; viz., 37° C. At 50° C. the organism shows very little activity and at 55° its activity ceases altogether. Nitrification, however, according to Warington, cannot be started in a solution if the initial temperature is 40°. C.

Desiccation has the same retarding influence on nitrification that a high temperature has. Even thoroughly air-drying a soil may suspend its nitrifying activity.

Darkness is also necessary to the proper progress of nitrification. In a strong light the activity of the organism is very much diminished or destroyed altogether. A bright light like sunshine may even stop nitrification which has set in.

Development of Nitric and Nitrous Acids in Soils.

Owing to the solubility of nitrates there can be but little accumulation of them in soils upon which there is any considerable amount of rainfall. On the other hand, in arid regions extensive deposits of nitrates may be found. The occurrence of a certain quantity of nitrates in the soil, however, is essential to the growth of plants. Until within a few years little was known of the origin of nitric acid in the soil. The presence of nitrates in drainage waters was well established, likewise the consumption of nitric acid by the growing plant, but the method of its supply was unknown. In a general way it was said that the nitric acid came by electrical action and the oxidation of proteid bodies in the soil, but without

specifying the manner in which this change takes place. The researches of Schloesing and Müntz, Springer, Winogradsky, Frankland, Warington and others have demonstrated the fact that this oxidation is caused by means of bacteria and that the nitrates formed can be consumed and destroyed by other species of this organism. In the one case the process has been called nitrification and in the other denitrification.[a/]

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a/ Principles and Practice of Agricultural Analysis, Vol. I, p. 460.

Order of Oxidation.

It is definitely determined that the activity of the ammoniacal and nitrous organisms is the first step in the process since the nitric organism appears to have no power whatever to oxidize proteid compounds while, on the other hand, the nitrous organism cannot, in any case, complete the conversion of nitrous into nitric acid. But although it is conceded that the action of the nitrous organism is precedent to that of the nitric, the two processes finally go on so nearly together as to prevent the accumulation of any large quantities of the lower salt in the soil. It is probable that the formation of ammonia precedes that of nitrous acid. Both nitrous acid and ammonia may be produced by the reduction of nitric acid but nitrous acid in this case is probably first formed giving rise to ammonia by further reduction.

The conditions which permit certain organisms to oxidize free nitrogen have not been definitely determined. The presence of such bodies in the tubercles attached to the roots of certain leguminous plants has been established. Winogradsky has isolated from the soil a nitrifying organism which is capable of converting free nitrogen into forms suited to nourish plant growth. This organism is cultivated in dextrose with careful exclusion of all nitrogen, save that which exists

in the air carefully freed of every trace of ammonia or oxidized nitrogen.

Under the influence of the growth of this organism the sugar undergoes a butyric fermentation, and nitrogen in an oxidized form is assimilated in an amount apparently equal to about one five-hundredth of the sugar consumed.

This result leads Warington to remark that it is a fact of extraordinary interest, both to the physiologist and chemist, that a vegetable organism, independent of symbiosis, should be able to acquire from the air all the nitrogen it needs.

Production of Ammonia in the Soil by the Action of Microbes.

It is highly probable that organic nitrogen in the soil in passing into the form of nitric acid exists at some period of the process in the form of ammonia. Marchal has isolated and studied some of these ammonia-making bacteria.[a/] Bacillus

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a/ Op. et loc. cit. supra.

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mycoides is the most active of these organisms. It occurs constantly in surface soils and is present in the air and in natural waters. In decomposing albumen it produces a strongly alkaline solution due to ammonium carbonate. Organic carbon, during this process, is converted chiefly into carbon dioxid, but small quantities of formic, propionic, and butryic acids are also produced. Any organic sulphur which is present is converted into acid. No hydrogen or nitrogen is eliminated in a free state. While slight alkalinity is favorable to the development of this bacterium, yet it may be propagated in a feeble sulphuric acid solution when the acid is less than one per cent.

The greatest activity of this organism is manifested at 30°C. Below 5° and above 42° no ammonia is produced. The bacillus will not develop in an atmosphere of hydrogen or carbon dioxid,

except in solutions of organic matter and nitrate. In addition to its action on egg albumen it decomposes other proteid bodies as well as leucin, tyrosin, creatin, and asparagin. It, however, does not oxidize urea, nor does it develop in solutions of ammonium salts and nitrates, except as mentioned above. When soluble carbohydrates are present, acids are formed. It is concluded from these experiments that the final oxidation of organic nitrogenous matter is preceded by its conversion into ammonium carbonate.

The Nitrification of Ammonia.

The same organisms which convert organic nitrogen into nitrous acid act also on ammonia and its compounds with a similar result. In fact, the formation of ammonia may be regarded as one of the stages on the road from albuminoid to nitric nitrogen.

Data have been collected by Schloesing on the nitrification of ammonia taking place in arable soil, tending to show that this phenomenon is accomplished without appreciable loss of nitrogen in the gaseous state. This, however, does not hold good when the quantity of ammonium carbonate introduced into the earth is largely increased. In two experiments, conducted by Schloesing, with a larger quantity of ammonium carbonate, the loss of nitrogen was very notable. In certain conditions the production of nitrous acid may take place, and it is interesting to know whether the appearance of nitrates has any influence on the disengagement of free nitrogen. In order to determine this question a solution of calcium nitrite was prepared by decomposing silver nitrite with calcium chlorid. From the results of the experiments made it was seen that the nitrites were only the results of a retarded and partially incomplete nitrification. They are, moreover, thus an obstacle to the normal work of the nitrifying organisms. It is also established that when they are present a disengagement of gaseous nitrogen takes place, whether the nitrites are formed

during the progress of the experiment, or whether they were originally present. However, it is not best to say that the nitrites themselves have been the cause of the disengagement of the nitrogen. It may happen that the disengagement of the nitrogen and the presence of nitrites are simply simultaneous as due to one and the same cause. The destruction of nitrates in the midst of reducing agents furnishes, according to the nature of these bodies and the circumstances, nitrous acid, ammonia, nitrogen dioxid, nitrogen protoxid, and free nitrogen.

This destruction of nitrates and the appearance of oxids of nitrogen and of free nitrogen are more likely to be due to the presence of a separate denitrifying ferment as pointed out by Springer than to have arisen in the manner mentioned above by Schloesing. In the present state of our knowledge, moreover, we can hardly regard the presence of nitrites as an obstacle to complete nitrification. On the other hand, it seems to be well established that the production of nitrites or ammonia is a necessary step between organic nitrogen and nitric acid.

Effect of Potassium Salts on Rate of Nitrification.

Dumont and Crochetelle have described some experiments to determine the effect of potassium salts alone in combination with lime on nitrification.[a/]

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a/ Principles and Practice of Agricultural Analysis, Vol. I, p. 463.

Soil rich in vegetable mold (18.5 per cent. of humus and 0.29 per cent. of lime) was treated with varying amounts of potassium sulphate and carbonate and kept for twenty days at 25°C. In the untreated soil the amount of nitric acid produced was twenty-five per cent. per million. When potassium carbonate was applied in quantities of from one tenth to six per cent. the amount of nitric acid increased from forty-seven parts per million to 438 parts when four and one half per cent.

of the potassium salt were used. Larger quantities caused a decrease in the amount of nitric acid produced. Very little effect, on the contrary, was produced by the action of potassium sulphate. When one half per cent. was employed the quantity of nitric acid formed rose to fifty parts per million, while with quantities as high as five per cent. it fell below the normal; viz., twenty-five parts per million.

When calcium carbonate was added to the soil in conjunction with potassium sulphate there was a marked increase in the amount of nitrogen oxidized. The activity of potassium sulphate in promoting nitrification is therefore increased by the presence of the calcium salt, potassium carbonate and calcium sulphate being formed.

Occurrence of Nitrifying Organisms.

According to the observations of Schloesing and Müntz the nitrifying organisms are widely distributed. Arable soil containing considerable humus and well supplied with calcium carbonate seems to be the medium in which they grow most freely and in which they accomplish their most important functions. Sewage waters are also rich in nitrifying ferments, as, in fact, are all waters containing organic matter. They are also found in running waters but not in great numbers. These ferments affect chiefly the surface of bodies, and especially are found on the bottom of culture-flasks. The authors named above have not found the nitrifying organisms in normal air. They could not seed sterilized flasks by admitting air freely. The absence of these ferments from the air is explained by reason of their sensitiveness to desiccation.

The method used by Schloesing and Müntz for the separation of the organism consisted in the preparation of original and subcultures in sterilized solutions containing nitrifiable matters. The proof of isolation was assumed when a given subculture contained only one kind of organism, as described by

the authors, was that of the latter isolations by Warington and Winogradsky, but the method used could hardly now be regarded as decisive.

Determination of the Nitrifying Power of Soils.

In studying the distribution of the nitrifying organisms in a soil the general method of procedure is based on the production of nitrification in a convenient solution by the organisms present in a given sample of soil. If the solution seeded with the given portion of soil remain unaffected, it will show that there were no nitrifying orgnisms present in the seed used. On the other hand, the vigor of the nitrifying process when once it is started, may be taken as an evidence of the number and activity of the organisms in the soil, a sample of which was used for seed. Based on these general principles the methods of study which follow were developed and applied. The object of the study was not to isolate the nitrifying organisms present in soil samples, nor to determine in any way their life history, but to ascertain by the rapidity and magnitude of the chemical changes they produced, the relative measure of their power to convert a nitrifiable base into nitric acid.

Plan of the Investigation.

The investigation of problems connected with the phenomena of nitrification in the soil was begun in the Autumn of 1894, and, after certain preliminary experiments, in the Spring of 1895 an extended study of the relative nitrifying power of typical soils occurring in various parts of the United States, and of the distribution of the nitrifying organisms at various depths in each of the localities whence samples of soils were received was inaugurated. Incidentally a determination was made of the effect of acidity upon the activity of the nitrifying organisms found in each of these soils. A brief summary

of the results of the part of the work last named was published in 1896.[a/]

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a/ Amer. Chem. Soc., 1896, 18; 475.

The method adopted after preliminary investigations consisted in the observation of the rate of nitrification in a solution of ammonium sulphate and nutritive salts when seeded with a small quantity of the soil under investigation. All possible precautions were taken to exclude atmospheric organisms and to prevent the undue drying of the soils while the operations of sampling, transportation through the mails, and the seeding of the cultures were executed.

Soil Sampling.

The agricultural experiment stations named below assisted in selecting the localities whence samples were to be taken at the respective stations, and secured and forwarded the soils. Without this cooperation on the part of these stations, it would have been impossible to obtain so representative and valuable a collection of samples as was received from the stations which responded to the circular letter issued in the Spring of 1895. As shown in table 59, twenty stations collaborating in the work sent sets of samples of both cultivated and virgin soils from forty-five localities in the United States.

(Table 59).

The samples used for nitrifying investigations were taken by means of small brass tubes similar to those used by the Bureau of Soils for the transportation of soil samples for moisture determinations. These tubes were six inches long and three fourths of an inch in diameter. One end was sharpened to a cutting edge and so constructed that the diameter of the cylinder of soil entering the tube was somewhat smaller

than the internal diameter of the tube. The other end of the tube was closed with a plug of sterilized cotton. After the tubes were sterilized in a hot air sterilizer both ends were covered with sterilized rubber "finger cots," in the rounded ends of which rubber "jackstone balls" were placed to prevent the cutting of the "cots" by the edges of the tubes. In fig. 14 is shown the form of the apparatus just described.

Four samples were taken in each locality at points three inches, fifteen inches, twenty-seven inches and thirty-nine inches below the surface, respectively, in accordance with the follwing directions. By following carefully the directions given below, it will be possible to secure small samples of soil free from other microorganisms than those normally contained therein.

The tubes and their rubber caps have been carefully sterilized and should not be removed from their cloth envelopes until the moment of taking each sample. After the sample has been taken and the cap replaced on the tube, the latter should be immediately enclosed in the cloth sack and labeled with one of the tags therewith enclosed. The sample should be taken in two kinds of soil, in one instance in the arable soil, which is most characteristic of the station plots, and in the second place a virgin soil of the same type. The virgin soil may be either soil which has been covered with grass or in forest. The spots at which the samples are to be taken having been previously selected, the tags for each tube should be prepared beforehand so as to avoid delay at the time of sampling. A pit with straight walls should be dug, the sides of which are at least two feet wide and even three feet would be better. The pit should be about 42 inches deep. One of the sides having been made perfectly smooth, and without allowing the loose fragments from the top to fall down and adhere to the walls below, the spots at which the samples are to be taken should be marked with a tapeline at the following points, viz., 3, 15, 27 and 39 inches respectively, below the surface. Beginning at the bottom point, carefully scrape off

the surface of the well over an area slightly larger than that of the end of the sample tube by means of a spatula, which, just previous to use, has been held for a moment or two in the flame of an alcohol or other convenient lamp. The sample tube having been removed from its sack, it will be noted that the end covered with black rubber is the one which is to be held in the hand, and this black rubber cap should be first removed being careful not to extract the plug of sterilized cotton which closes the end of the tube. Holding the tube firmly by the end, the fingers extending only about two inches from the end, remove the light colored cap and push the tube with a turning motion into the side of the pit at the point where the surface has been removed with the sterilized spatula. When this is properly done the tube will be filled with a cylinder of soil equal to the length of the part of the tube penetrating the wall of the soil. The tube is then withdrawn, the light rubber cap first replaced and then the black one. The light rubber cap should be held in the hand during the process in such a way that no dust or particles of soil are permitted to contaminate its inner walls. For this purpose the open end of the cap should be held downward. For the same reason after the removal of the light rubber cap the brass tube should be carefully preserved from dust or fragments, the open end, that is the cutting end, being held downward until ready for use. After one tube has been filled, capped, replaced in the sack and labeled, the spatula should be again sterilized and samples taken in regular order until the top one is finished. The tubes should be sent by mail, the tag being used as a frank.

Each station furnished complete data in regard to the previous history and character of each soil sampled, which will be found in table 59 of Part II of this report. The character of the soils and of the successive strata forming the subsoils is set forth graphically in figs. 15 to 20, inclusive. The numbers used for the identification of the soils on these graphic charts are the numbers used to designate the cultures

made from each of them respectively, and their signification may be learned by reference to table 59.

The quantity of soil transmitted in the tubes described above was much greater than was needed for seeding the cultures, but it was necessary to take the amount in order to obtain a representative sample. Each sample was thoroughly mixed before removing the portions for the inoculations. For this purpose a number of small Erlenmeyer flasks were plugged with cotton and sterilized in a hot-air sterilizer. Each tube was then carefully opened and its contents pushed into one of the sterile flasks with the aid of a large sterilized glass rod of a diameter slightly less than the internal diameter of the tube. These manipulations were conducted under a glass hood, with the customary precautions for the transfer of materials from one piece of apparatus to another without contamination with atmospheric organisms. (See fig. 21.)

Before the flasks were again closed, the lumps of soil were broken up and thoroughly mixed with the fine soil by means of a sterilized glass rod or a sterilized platinum spatula.

The Culture Medium and Seeding.

The solution of ammonium sulphate and nutritive salts used as the culture medium for this series of investigations had the following composition:

	Grams
Ammonium sulphate	0.942
Potassium phosphate	1.000
Magnesium sulphate	0.500
Calcium chlorid	trace
Distilled water	1000.000

The chemicals used were the so-called "chemically pure" reagents at hand in the laboratory at the time. The solution did not contain more than the merest traces of organic matter.

One hundred cubic centimeters of this solution were placed in each of several sterilized Erlenmeyer flasks of 150 to 200 cc capacity. The cotton plugs were returned to the flasks,

glass caps were placed over them, and the flasks thus charged were sterilized in an Arnold steam sterilizer in the usual manner, being steamed for the proper length of the time on each of the three successive days. Some freshly precipitated and carefully washed calcium carbonate was also prepared and sterilized in similar flasks, after mixing with such a quantity of water that 5 cc of the well-shaken mixture contained in suspension a little more than 0.2 gram of calcium carbonate.

It is believed to be impracticable to weigh the portions of soil used for seeding the cultures without contaminating them with organisms contained in the air and adherent to floating dust. Moreover, since the moisture content of the samples varies considerably, it was thought that a measured quantity would be more satisfactory than one weighed. Portions of each sample were therefore transferred to each of three culture flasks by means of a sterilized platinum spoon holding between 0.4 and 0.5 gram of a moderately moist soil. To each of two of the three flasks seeded with a given sample, there was added by means of a sterilized pipette approximately 0.2 gram of the sterilized calcium carbonate referred to above. No calcium carbonate or other agent for the neutralization of the nitrous and nitric acids formed, and the sulphuric acid set free as the nitrification progressed, was added to the third flask seeded with each sample of surface soil. Those cultures to which no calcium carbonate was added are designated by the letter "B." From this series of cultures containing no neutralizing agent the data in regard to the influence of acidity upon the activity of the nitrifying organisms referred to in this paper and in the Journal of American Chemical Society[a/] were obtained.

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a/ J. Amer. Chem. Soc. 1896, 18; 475.

In the case of each sample taken at a greater depth than three inches only two cultures were prepared and to both of

these calcium carbonate was added. In table I, a given pair of duplicate cultures are designated by the same number the letter "R" being placed after the number in the case of one of them.

Temperature Conditions.

A thermostat of sufficient dimensions to hold all of the cultures was not available. The culture of flasks were therefore placed in a dark closet, the temperature of which varied with that of the laboratory air. The fluctuations were unfortunately very considerable, and their effect on the rate of nitrification was very marked, as will readily be seen on examination of the data presented below. The readings of a maximum and minimum thermometer, kept in the culture closet, were recorded each day. Series of cultures were seeded on May 3, 9, 18, 27, June 5, 19, 26, July 13, 19, September 10, October 12 and November 15, 1895. Temperature charts, figs. 22 to 33, inclusive, show the maximum and minimum daily temperature throughout the period of eight weeks following each of these dates.

Progress of Nitrification.

At the end of each week following the seeding of the cultures, each culture was tested for the purpose of ascertaining the amount of nitrification accomplished during the preceding seven days. Diphenylamin and concentrated sulphuric acid were the reagents used for this test at the end of the first week. At the end of each succeeding week throughout the observation period of eight weeks the amounts of nitrous and nitric acids were determined. For these tests the appropriate portion, and no more, of the culture fluid was removed from each culture flask and transferred to the tube or evaporating dish in which the test was made. A separate sterilized pipette was used

for the removal of the liquid from each flask. The descriptions of the soils, the culture of numbers, the dates on which cultures were seeded, the dates on which tests were made and the results thereof, etc., will be found in table 1.

Methods of Testing for Nitrous and Nitric Nitrogen.

Preliminary Tests with Diphenylamin.

Diphenylamin and concentrated sulphuric acid are used for the purpose of ascertaining the time at which nitrification begins because they react with both nitrous and nitric acids. The depth of the blue color produced by the action of the nitrates or nitrites upon diphenylamin in the presence of concentrated sulphuric acid varies considerably with the temperatures and strength of the acid. For the purpose of obtaining comparable results it is necessary that a uniform method of manipulation should be used, and after a number of experiments the following process was adopted:

> To 1 cc of the culture solution to be tested which is transferred from a culture flask to a dry test tube by means of a sterilized pipette, there is added 1 drop of a solution of diphenylamin in 4 cc of concentrated sulphuric acid. The tubes are well shaken and immediately placed in a water bath at 80° and kept therein at this temperature for 15 minutes. Until this method of manipulation was adopted, it was difficult to obtain agreeing results when duplicate tests of known solutions were made.

Method for the Determination of Nitrous Nitrogen.

After trials of various methods the napthylamin and sulphanilic acid method was adopted.[a/] The method of manipulation

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a/ Principles and Practice of Agricultural Analysis, Vol I, p.560

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is substantially that in use in water analysis with several important modifications which will be described. The principal difficulty arises from the fact that in the latter part of the culture period of eight weeks the quantity of nitrites developed

by many of the soils is so great that in some of the solutions the color produced is very deep and even results in the production of a precipitate. This difficulty is obviated by the following method of manipulation.

Two and one half cc of the culture fluid are transferred to a graduated cylinder by means of a sterilized measuring pipette. A large quantity of distilled water is kept at hand to which has been added the proportion of napthylamin, sulphanilic and acetic acids usually employed in the determination of nitrites in water. The portion of culture fluid contained in the graduated cylinder is diluted at first to about 100 cc and the dilution continued as the color developes, being conducted more rapidly in the case of those tests which show the presence of greater amounts of nitrous nitrogen.

The standard solutions for comparison containing known quantities of nitrous acid are prepared simultaneously with the unknown solutions. At the end of twenty minutes or half an hour the observation is begun and is conducted in 50 cc of Nessler cylinders, the comparison being made by means of transmitted light. A comparison camera similar to those used in iron and steel laboratories for carbon determinations is employed. The total volume of the solution and the number of the standard tube which matches a given unknown solution are recorded and the process is complete with the exception of the calculation.

It will be noted that acetic acid is used as the acidulating reagent for this test. Moderately strong acidulation is required to prevent precipitation of the colored reaction product, particularly when the color is very dark. Strong acidulating with acetic acid is found most satisfactory for this purpose.

Methods for the Determination of Nitric Nitrogen.

For this determination a modification of the picric acid method is employed. Phenol-disulphonic acid is used, prepared

according to the directions of Gill.[a/] The culture media con-

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a/ Determination of Nitrates in Potable Water, J. Amer. Chem. Soc., 1894; 16; 122.

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tained only traces of chlorin, therefore precautions were unnecessary to eliminate errors arising from the presence of this substance. The test is conducted as follows:

> Two and a half centimeters of culture liquid are transferred to a small porcelain dish by means of a sterilized measuring pipette. One drop of sodium carbonate solution is added and the liquid evaporated to dryness. The residue is treated with the proper quantity of phenol-disulphonic acid reagent which is brought in contact with every part of the residue by means of a short stirring rod. Ten cubic centimeters of water and 3 cc of strong ammonia water are added and the unknown solutions are compared with a standard solution prepared at the same time. A Duboscq colorimeter may be used for the comparison.

Discussion of Results.

The extent of the agreement of duplicate cultures and the general character of the results are exhibited by the curves on the charts, figs. 34 to 40, showing the comparative results on samples Nos. 5, 15, 17, 29, 30, 33 and 53. In each case the two sets of continuous and dotted lines represent duplicate samples of the same soil exposed to the same conditions. Any differences in results must therefore be attributed to lack of uniformity in number and vitality of the organism present and introduced into the growth medium of seeding. The heavy lines represent the original sample and the light lines the duplicate. The dotted lines in each case show the quantity of nitrous acid present at the end of each week of the culture period, while the number at the side of each diagram shows the parts per million present. The continuous lines show the sum of the quantities of nitrous and nitric acid present at the end of each week of culture. The difference between the two lines at any given point show the quantity of nitric acid alone. The charts selected are those which are typical of the general results. It is not deemed advisable, however, to print a

larger number of the graphic charts than will serve to illustrate the reactions which took place, although such charts were made for each individual experiment. The number of pots corresponding to the sample is given in order that the data may be referred directly to the actual results obtained from the pot culture.

Sample No. 5.

In sample No. 5 it is seen that the nitrification has only just commenced at the end of the first period, the quantity of nitric acid present being, approximately, a half of 1 part per million in each of the duplicate samples. The first sample, represented by the heavier continuous line, shows a more marked nitrification at the end of the second week, the total quantity of nitrous acid present being 2 parts per million, and the total quantity of both acids being, approximately, 2-1/2 parts per million. A duplicate sample meanwhile shows a total nitrification of only about 1 part per million. At the end of the third week the nitrous acid has risen to 6 parts per million, and the two acids to a little more than 9 parts per million, showing, approximately, the presence of 3 parts per million of nitric acid and 6 parts per million of nitrous acid in the first sample, while the second sample has only still a little over 1 part per million of nitrous acid. At the end of the fourth week the nitrifying ferments begins to gain upon the one producing the nitrous acid, both in the original and duplicate sample. In the original sample the nitrous acid has fallen to 2 parts per million, while the total acids has risen to almost 11 parts per million, showing nearly 9 parts per million of nitric acid. In the duplicate sample there is approximately 1/2 part per million of nitrous acid and 8 parts per million of both acids, showing 7-1/2 parts per million of nitric acid. At the end of the fifth week the nitric ferments have gained a distinct victory. They have consumed all of the nitrous acid which has accumulated and convert any which is still formed at once into the nitric condition. The original

sample shows 50 parts per million of nitric acid and no nitrous acid. The duplicate sample shows 25 parts per million of nitric acid and no nitrous acid. From this point up to the close of the experiment at the end of the eighth week there is no accumulation of nitrous acid whatever, and the nitrification in the two samples progress almost at the same rate. At the end of the period the original sample has 170 parts per million and the duplicate sample 140 parts per million of nitric acid.

Sample No. 15.

The chart of this sample shows a very distinct variation from that of sample No. 5. The nitric ferment in the original sample does not begin to show its activity until about the middle of the fifth week, while in the duplicate sample mere traces of nitric acid have been formed up to that time. It was not until the end of the seventh week in the original sample that the nitric ferment begins to assert its superiority, while in the duplicate sample it begins to become the dominant factor at the end of the seventh week. At the end of the ninth week the nitric ferment has established its complete equality with the nitrous ferment, although the amount of nitrous acid is still very large, being 90 parts per million. In the duplicate sample the nitric ferment has entirely vanquished its colaborer, the nitrous acid having entirely disappeared. The sum of the two acids in the two samples at the end of the ninth week is almost exactly the same, being 200 parts per million in the original sample and 220 parts per million in the duplicate. This soil is a fine example of the rapid working of the nitrous ferment and the slow working of the nitric ferment.

Sample No. 17.

This chart is given to show the great similarity existing between this sample and sample No. 5. This soil, like sample No. 5, is one in which the nitric ferment speedily gains the

mastery and holds it up to the end of the experimental period.

Sample No. 29.

This chart shows still a different type of nitrification. Without going into great details, which can be obtained easily by a study of the chart itself, it is seen that in these duplicate samples the progress of the two ferments in the two samples is quite uniform up to the end of the seventh week. During the eighth week the original sample maintains about the same quantity of nitrous acid, viz., 110 parts per million, while the duplicate sample begins rapidly to lose.

Sample No. 30.

This chart is given especially to illustrate the difference in the nitrous ferments in duplicate samples. In the original sample the nitrous ferment is very vigorous as compared with the nitric ferment up to the end of the seventh week. In the duplicate sample the nitrous acid rapidly disappears and is not found after the end of the seventh week; yet the total degree of nitrification in the two samples is almost identical, being 230 parts per million in the original sample and 220 parts per million in the duplicate sample at the end of the ninth week.

Sample No. 33.

This chart shows another remarkable type of nitrification, indicating that even at the end of the eighth week scarcely any nitric acid has been formed. This is a soil in which the nitric ferment is either very weak in number or in vitality, while the nitrous ferment is extremely vigorous, or it may be that a denitrifying organism reduces to lower forms of oxidation the products which result from the activity of the nitric ferment.

Sample No. 53.

T is chart illustrates better than any of the others the uniformity of activity in the two samples. In so far as nitrous acid is concerned the two samples are practically identical in the development and disappearance of this element, while with the nitric acid the agreement is almost as satisfactory. At the end of the fifth week the nitrous acid has entirely disappeared, while the progress of nitrification advances with even pace for the two samples up to the end of the eighth week, when the observation is discontinued.

Graphic Presentation of Results.

In order to represent the data obtained in the most compact and graphic manner possible, it was decided to plat them as shown in figs. 41 to 53, inclusive. On these charts are shown the nitrous and nitric forms of nitrogen, represented in parts per million of the culture medium produced by 176 culture experiments in samples of soils taken at various depths as indicated. The shaded portions represent nitrous nitrogen and the solid black portions, nitric nitrogen. Ordinates, or the distances from the top to the bottom of the space given to each culture denote time, the entire time of the culture period being eight weeks. The abscissas, or distances from left to right, denote parts per million of nitrogen. For example, if we place a ruler across one of the spaces, with the edge parallel to the horizontal boundaries of the space and at three fourths of the distance from the top of the space toward the bottom, the length of the shaded area measured at the edge of the ruler in terms of the divisions at the top of the chart will indicate the number of parts per million of nitrogen present in the culture in the form of nitrous acid or nitrites at the end of the sixth week of the culture period; the length of the solid black area measured in the same manner will indicate the number of parts per million of nitrogen present in the form

of nitric acid or nitrites on the same date; and the total length of the two will indicate the total amount of nitrification which has taken place during six weeks.

Summary.

Leaving out of consideration a few anomalous results which must be expected to attend chemical investigations depending largely or entirely upon the activity of living organisms, the data presented are interesting and instructive.

On inspection of table 59 it will be found that the duplicate cultures give, in most cases, tolerably concordant results. The extent of the agreement of duplicate results can, however, be more readily studied by the use of the charts on which are given the curves representative of the progress of the nitrification of individual cultures. (Figs. 34--40.).

This work confirms the results of other investigators in regard to the generous distribution of nitrifying organisms in the upper layers of the soil. Soils from forty-five localities are represented in this investigation. In only four cases was no nitrification whatever obtained with all of a given set of four samples taken to one place. No nitrification was obtained with the samples of virgin soils received from Wisconsin, Kansas, South Dakota, and Montana. Nitrification would doubtless have been obtained with these soils if the amount of soil used in seeding the cultures had been greater. Surface soils may sometimes be partly sterilized in so far as the nitrifying organisms are concerned by natural desiccation and the temperatures due to insolation in summer. On inspection of the graphic charts, figs. 41 to 53, presenting the mean results of duplicate cultures, the extent to which nitrifying organisms are confined to surface soils in the majority of cases is very apparent. Another characteristic of the nitrification obtained with samples taken at some distance from the surface was the tardiness with which the nitrites formed were changed

into nitrates. This is well exhibited by inspection of the graphic charts to which reference has just been made. This fact indicates that the organisms producing nitrous acid retain their activity at greater depths than those converting nitrous into nitric acid.

These results combined with the well-known fact that the rate of nitrification in the soil of a given locality increases as the season proceeds, confirm the opinion generally current at present, that in most cases an endeavor to bring about those conditions which favor the activity of nitrifying organisms will be productive of better results than any attempt to seed a soil which nitrifies slowly with nitrifying organisms. These favorable conditions are the presence of a proper amount of moisture, a nitrifiable base to combine with the acid produced, a good summer temperature, and a well aereated soil. It is certainly clear that such conditions must be present in every case or these organisms cannot thrive and perform their functions. The influence of temperature is well shown by the temperature and other graphic charts presented. It is evident that the best conditions for nitrification are also those most favorable to plant growth. Thus nature furnishes the most abundant supplies of available nitrogen at a period when they are most needed. The practical suspension of nitrification in cold weather and in areas under water prevent the waste of this most costly plant food.

The effect of acidity upon the nitrifying organisms is strikingly shown by the small amount of nitrification which occurs in those cultures to which no calcium carbonate is added. The cultures are designated by placing the letter B after the culture number which is used to denote the culture containing calcium carbonate seeded with soil from the same source. Reference to the last two charts shows that only in rare cases does the nitrification in the absence of calcium carbonate exceed 25 parts per million. In the cases in which decidedly more nitrification occurs it is found that the soil with which

the cultures are seeded is very highly basic, one of them containing so much calcium carbonate that an effervesence with the acids is obtained. The data shows that the excellent effects produced by liming are largely due to the creation of an environment favorable to the increased activity of the nitrifying organisms.

General Summary.

1. Soils are not homogeneous in structure; thus in soils taken in the same locality great differences are found. Soils from widely separated localities show, under identical conditions of growth, large variations in yield. The individuality of soils is as marked as that of men.

2. Differences in yield of various soils under given conditions are determined solely by the availability of plant food, for if any of the essential elements is absent no crop can be produced no matter how abundantly the other plant foods are supplied. The availability of plant food is a term expressing the degree to which it becomes useful in plant growth and it is determined chiefly by two factors,-- first, the condition in which it exists as regards solubility; and second, the condition in which it exists respecting the penetration of the roots of plants throughout its substance, and the circulation of water therein. The first is a purely chemical condition and the second a physical one. An abundant supply of soluble plant foods in a soil impervious to the roots of a plant is of no value so long as these foods do not enter the root zone. The permeability of the mass in relation to the roots of the plant is of no value provided the mass contains no plant foods.

3. Culture in pots where identical conditions of growth can be secured, with the exception of those inherent in the soil, is not to be considered as a condition of agriculture similar in all respects to that in the open field. In pot cultures the small masses of soil are entirely isolated from the earth. There is no movement of soluble particles from the large mass of the earth to the small mass surrounding the growing plant as is the case in the open field. The further fact that during the winter months in the cultures which have been described, the soils in a reasonably dry state, were protected from the influence of the weather, is another condition which is different from that in the open field. The result is evi-

dent, namely, that the available plant food in such isolated masses of soil necessarily must be decreased far more rapidly than in open cultures. This fact, however, does not diminish the value of the comparative tests which are made, since all the samples are submitted to the same conditions. The inferences, therefore, which are drawn from pot cultures can be applied, with the restrictions above noted, to field culture.

4. The chief factors in the solution of plant food in the soil are as follows: For nitrogenous foods existing in the organic form, nitrifying and bacterial activity; for phosphoric acid, potash and lime, (1) water charged more or less with carbon dioxid, (2) soluble salts, (3) the solvent action of the roots or exudations therefrom, and (4) acids incident to the fermentation, necessary to the completion of the nitrifying processes in organic matter. This organic matter is due to previous crops, the addition of fertilizers, and derived from humus. A soil solvent is thus seen to be a complex of a very intricate nature, the character of which is constantly changing in the efforts continually going on in the soil towards the restoration of a chemical equilibrium disturbed by the demands of the growing plant.

5. In soils of a very acid nature such as a vegetable mold commonly known as "muck," phosphoric acid in the form of tricalcium phosphate is much more available for plant nutrition than are similar compounds in neutral or alkaline soils. In the latter class of soils tricalcium phosphate is very slowly broken up and the phosphoric acid which it contains is therefore less speedily available. In such soils the addition of phosphoric acid in the form of ground bone or ground phosphate rock is not advisable when immediate returns are desired. When tricalcium phosphate is employed in States having such soils it is evident that the material should be as finely ground as possible in order to secure the desired results.

6. In acid vegetable soils similar to those described

there is less difference, in so far as crop production is concerned, whether the phosphoric acid be applied in the form of tricalcium phosphate, basic slag or acid phosphate. In the case of neutral or alkaline soils, however, the phosphoric acid is much more active when applied in the form of basic slag or acid phosphate than in the form of tricalcium phosphate.

7. When the condition of a soil is such as to produce only minimum crops the percentage of the abundant available plant foods in such crops is greatly increased over that which is found in crops of maximum magnitude. This indicates that the excessive percentage of these plant foods in minimum crops is due rather to mere absorption than to physiological use. This deduction is strongly supported by many data in the preceding pages and it also teaches that in the economic production of crops the best returns, in so far as the utilization of plant food is concerned, are always secured with maximum crops. This may be illustrated more forcibly by the following example: Ten dollars worth of potash, in one instance applied to a crop approaching a minimum may produce only 500 pounds of dry matter per acre while the same amount of potash on a crop approaching a maximum may produce 5 tons of dry matter per acre. In the latter case it is seen that the potash utilized is twenty times more effective in the large crop than in the small. This increased efficiency is due to the proper balance of the crop rations in such a manner that the least abundant element is sufficient for a maximum crop production. This shows that in field culture the farmer in order to utilize plant foods most economically should always strive to attain those conditions of culture and fertilization which combined with a favorable climatic environment will produce a maximum yield.

8. The vitality and activity of nitrogenous organisms in the soil, without which the organic nitrogen therein can not be utilized as plant food, vary as greatly as the chemical and physical composition of the soils themselves. The data show that the most active organisms are contained in the first foot

of the soil, the number of nitrifying organisms rapidly diminishing at a lower depth and almost ceasing to exist at three feet below the surface. The data further show that in the nitrification of an ammoniacal base the activity of the nitrous ferment precedes, as would naturally be supposed, that of the nitric ferment. During the course of nitrification the activity of the nitric ferment increases while that of the nitrous ferment comparatively declines. Thus it happens that even during the course of nitrification often no nitrous acid can be detected. The data further show that the greatest activity of the nitrifying ferment is coincident with the period of crop growth. During the winter months the nitrifying organism lies practically dormant. Since nitric acid and nitrates are extremely soluble in water and the soil itself has no tendency to retain either nitric acid or nitrates in solution the above fact is of great economic importance. Should nitrification continue at low temperatures as vigorously as at high the stores of nitrogen in the soil would be rapidly exhausted, and the soil would with corresponding rapidity become sterile.

9. A large percentage of American soils appear to be inclined to acidity. This state, while favoring in some soils, such as those composed largely of humus, the solubility of phosphoric acid, potash and lime, is extremely detrimental to the activity of nitrifying ferments. Great benefit, therefore, accrues to most American soils from the addition of lime, usually in the form of hydrate or carbonate. Soils which seem to have almost no nitrifying power and in a natural state and which give small crops produce vigorous nitrification and large crops when treated with carbonate of lime. This is one of the most important facts developed in the experimental work with nitrification.

10. The phenomenon of vitality in plants and animals is distinguished by one very important characteristic, in so far

at least as plants bearing chlorophyll cells are concerned. Plants consume nitrogen only in the oxidized state; animals consume introgen only in the organic state. Non-chlorophyll bearing plants in this respect may resemble animals inasmuch as the nitrifying bacteria which consume protein are supposed to be more nearly related to plant than to animal life. There are contained in soils and manures denitrifying organisms which consume nitric acid and reduce it to lower forms of oxidation and even to free nitrogen. These organisms are normally present in soils, in manures, and in crop residues, such as straw and stubble. Happily they seem only to exert their greatest activity in the presence of such an excess of organic matter and under such conditions of aeration as seldom obtain in well tilled soil of good quality and location. The losses of nitrogen which are induced in this way are made good by chemical and biological processes which provide additional stores of nitric nitrogen for plant use. Chief among these may be reckoned electrical action and the work of certain forms of nitrifying the free nitrogen in the atmosphere directly or in symboiotic relation with certain green plants, such as legumes. Through these sources the losses of nitrogen due to the activity of denitrifying organisms are compensated for and the amount of nitrogen available for plant food may even be increased.

11. The amount of plant food which may exist in the soil must be regarded, in relation to chemical analysis, under three different heads:

a. The total quantity of matter in the soil which may be utilized as plant food, namely, total nitrogenous matter, total phosphoric acid, total potash, total lime, etc. This total quantity of matter can be determined with the greatest accuracy possible to chemical manipulations and the results give the total potential ability of the soil to produce crops over a long series of years.

b. The quantity of the bodies above mentioned in the soil

which are soluble in certain reagents may be determined and regarded as the amounts of plant food in the soil which can be utilized within a reasonable number of years. The results of this kind of analysis give not only the quantities which are immediately available for plant use but also those which may become so, with the progress of time, derived from those mineral aggregates which are more or less advanced in the stage of decomposition.

c. The quantities of essential plant foods in the soil which may be regarded as immediately available, that is, if reached by the roots of plants, and which are capable of immediate assimilation may also be determined. The results of such an analysis would indicate the immediate possibilities of crop growth in the soil examined.

The chemical data which may be secured under heads "a" and "b," paragraph 11, are obtained by long established methods which are practiced in general by agricultural chemists. The methods of obtaining the results under "c" have been the subject of great discussion and many different methods and processes are in vogue. One of the objects of the experiments which have been described in the preceding pages was the study of such proposed methods as compared with the actual results obtained in pot culture and, if practicable, the establishment of a new method or the modification of an old one in such a way as to give more concordant and satisfactory data. It is, of course, understood that the only method of obtaining immediately available nitrogen is the one in common use, namely, treatment in water and the determination of nitric acid in the solution. Attention is paid principally, therefore, to the methods of determining the quantities of phosphoric acid and potash available for plant assimilation and checking the results by the determination of the actual quantities taken from the soilby the growing crop. It was deemed advisable if possible to use a single reagent in this process. After a careful trial of the proposed reagents it was found that very dilute hydrochloric acid offered the most promising results

when applied to the soil in such quantities that after the neutralization of the basic substance there was still present a quantity of hydrochloric acid equivalent in strength to a two hundredth normal solution used in the proportion of one liter to each 200 grams of soil. Water added to the soil, even when pure, becomes instantly a solvent which contains more or less of other substances. While such a solvent acts very readily upon potash, its action upon phosphoric acid, in the great majority of soil, may be regarded as practically nil. On the other hand, N/200 hydrochloric acid dissolves, in the soils subjected to experiment, quantities of phosphoric acid and potash, if present, in most soils of common composition in proportions almost equal to those which are removed by an ordinary oat crop. It may be said, therefore, as a result of the investigations, that if a soil be treated with N/200 hydrochloric acid under the conditions described and in the solution obtained there should be smaller quantities of phosphoric acid and potash found than are usually removed by oat crops of ordinary size, the indication is that the soil in question is not sufficiently fertile to produce profitable oat crops. Such soils are uniformly benefited by the addition of one or both of the constituents above mentioned which are found to be deficient. It is, of course, evident that should the data show each of the ingredients mentioned to be present in sufficient quantity it would not be a final proof of fertility because nitrogen or some other element may be present in insufficient quantity. If the condition of a soil renders it incapable of developing nitrifying organisms it is evident that no matter how much organic nitrogen may be present it can not be made available for plant growth without inoculation with the proper organism. This fact is illustrated in the case of certain vegetable soils containing large quantities of nitrogen but deficient in nitrifiable bases. Such soils need to be treated with lime before fertility can be established, as shown by the data on nitrification.

13. Heating ordinary soils for some time to the temperature

of boiling water tends to increase the quantities of phosphoric acid and potash soluble in N/200 hydrochloric acid. The fertility of these soils correspondingly increases provided they be inoculated with nitrifying organisms to take the place of those which are killed during the process of heating. This heating increases the quantity of soluble phosphoric acid and potash and the consequent increased fertility is doubtless due to the chemical changes in the hydrosilicates and the change in the colloid condition of the clays which the soil contains. The actual burning of the soil at a temperature which decomposes organic nitrogenous compounds could only result finally in the diminution of the potential fertility although the kinetic fertility may be temporarily increased after inoculation. The heating of soils, therefore, can not be recommended as a permanent method of increasing fertility.

14. Soils which are deficient in one or more of the essential plant foods in a form available for the use of plants, and soils which have been reduced by injudicious cultivation to a state of minimum fertility, may be made to produce crops of reasonable magnitude by the judicious use of fertilizing materials. The character and amount of such materials may be approximately foretold by chemical methods and are also determined by experimental tests. In all cases it is advisable that both chemical examinations and experimental tests be carried on at the same time since the information derived from both is of greater value than could possibly be derived from either alone.

15. The yield of many crops is determined largely by cultivation, for example, Indian corn and potatoes. Cultivation has but little influence on the yield of other crops such as forest products and grasses used for making hay or for grazing. Again the environment determines the comparative utility of the cultivation of certain crops, as, for instance, the sugar cane which will not yield a good crop in Louisana without cultivation but does so in Cuba for many successive years. Cultiva-

tion can never increase the total quantity of plant food in the soil but it is useful in many other ways, especially in aeration, in increasing the immediately available farms by increasing the permeability of the soil, and in modifying its water holding power. Rotation of crops can never increase the total fertility of the soil except in the case of leguminous plants which, by reason of their serving as a host for certain parasitic nitrifying ferments are capable of increasing the stores of avialble nitrogen. It is evident, therefore, that the only method of maintaining a high degree of soil fertility throughout a long series of years is the combination of a scientific system of cultivation and rotation with a reasonable and logical practice of adding to the soil from time to time the elements of plant food removed by crops and necessary to the production of crops of maximum magnitude.

16. The chemical study of soils and of the plants growing therein reveals the relations which exist between them and no system of scientific agriculture is complete which omits the consideration of the important bearing which chemistry has upon rational agriculture.

Table 1.-- Index to pots by soil numbers, showing locality from which soils were taken.

Locality	Soil No:	Pot numbers of oats		Pot numbers of beans		Locality	Soil No:	Pot numbers of oats		Pot numbers of beans	
		Surface soil	Subsoil	Surface soil	Subsoil			Surface soil	Subsoil	Surface soil	Subsoil
California	1:	1:	31:	2:	32:	Missouri	26:	82:	109:	83:	110:
Illinois	2:	3:	33:	4:	34:	Montana	27:	84:	111:	:	:
Do	3:	5:	35:	6:	36:	New York	28:	85:	112:	:	:
Indiana	4:	9:	38:	:	:	Oregon	29:	86:	113:	:	:
Iowa	5:	10:	39:	11:	40:	South Dakota	30:	87:	118:	88:	119:
Kansas	6:	7:	41:	8:	42:	Texas	31:	89:	120:	:	:
Massachusetts	7:	12:	44:	13:	45:	Wisconsin	32:	90:	121:	91:	122:
Michigan	8:	14:	46:	15:	47:	Pennsylvania	33:	129:	:	130:	:
Missouri	9:	16:	48:	17:	49:	Maryland	34:	29:	:	30:	:
Montana	10:	18:	50:	:	:	District of Col	35:	131:	:	:	:
New York	11:	19:	51:	:	:	Composit	36:	151:	:	:	:
Oregon	12:	20:	52:	21:	:	England	37:	156:	:	157:	:
South Dakota	13:	22:	55:	23:	56:	Do	38:	158:	:	159:	:
Texas	14:	25:	58:	26:	59:	Do	39:	160:	:	161:	:
Wisconsin	15:	27:	60:	28:	61:	Do	40:	162:	:	163:	:
Pennsylvania	16:	127:	:	128:	:	Do	41:	164:	:	165:	:
California	17:	63:	93:	64:	94:	Do	42:	166:	:	167:	:
Do	18:	65:	95:	67:	96:	Do	43:	168:	:	169:	:
Illinois	19:	69:	101:	:	:	Do	44:	170:	:	171:	:
Do	20:	70:	98:	71:	99:	Florida	45:	135:	:	:	:
Indiana	21:	73:	102:	:	:	Do	46:	139:	:	:	:
Iowa	22:	74:	103:	75:	:	Do	47:	143:	:	:	:
Kansas	23:	76:	104:	77:	105:	Do	48:	144:	:	:	:
Massachusetts	24:	106:	78:	79:	107:	Maryland	49:	147:	:	148:	:
Michigan	25:	80:	108:	81:	:	Nebraska	50:	125:	126:	:	:

Table 2.-- Index to soils by pot numbers.

Pot No	Soil No	Type of soil	Crop	Locality	Pot No	Soil No	Type of soil	Crop	Locality
1	1	surface	oats	California	78	24	subsoil	oats	Massachusetts
2	1	do	beans	Do	79	24	surface	beans	do
3	2	do	oats	Illinois	80	25	do	oats	Michigan
4	2	do	beans	do	81	25	do	beans	do
5	3	do	oats	do	82	26	do	oats	Missouri
6	3	do	beans	do	83	26	do	beans	do
7	6	do	oats	Kansas	84	27	do	oats	Montana
8	6	do	beans	do	85	28	do	do	New York
9	4	do	oats	Indiana	86	29	do	do	Oregon
10	5	do	do	Iowa	87	30	do	do	South Dakota
11	5	do	beans	do	88	30	do	beans	do
12	7	do	oats	Massachusetts	89	31	do	oats	Texas
13	7	do	beans	do	90	32	do	do	Wisconsin
14	8	do	oats	Michigan	91	32	do	beans	do
15	8	do	beans	do	93	17	subsoil	oats	California
16	9	do	oats	Missouri	94	17	do	beans	do
17	9	do	beans	do	95	18	do	oats	do
18	10	do	oats	Montana	96	18	do	beans	do
19	11	do	do	New York	98	20	do	oats	Illinois
20	12	do	do	Oregon	99	20	do	beans	do
21	12	do	beans	do	101	19	do	oats	do
22	13	do	oats	South Dakota	102	21	do	do	Indiana
23	13	do	beans	do	103	22	do	do	Iowa
25	14	do	oats	Texas	104	23	do	do	Kansas
26	14	do	beans	do	105	23	do	beans	do
27	15	do	oats	Wisconsin	106	24	surface	oats	Massachusetts
28	15	do	beans	do	107	24	subsoil	beans	do
29	34	do	oats	Maryland	108	25	do	oats	Michigan
30	34	do	beans	do	109	26	do	do	Missouri
31	1	subsoil	oats	California	110	26	do	beans	do
32	1	do	beans	do	111	27	do	oats	Montana

Table 2.-- Continued

33	2	subsoil	oats	Illinois	112	28	subsoil	oats	New York	
34	2	do	beans	do	113	29	do	do	Oregon	
35	3	do	oats	do	118	30	do	do	South Dakota	
36	3	do	beans	do	119	30	do	beans	do	
38	4	do	oats	Indiana	120	31	do	oats	Texas	
39	5	do	do	Iowa	121	32	do	do	Wisconsin	
40	5	do	beans	do	122	32	do	beans	do	
41	6	do	oats	Kansas	125	50	surface	oats	Nebraska	
42	6	do	beans	do	126	50	subsoil	do	do	
44	7	do	oats	Massachusetts	127	16	surface	do	Pennsylvania	
45	7	do	beans	do	128	16	do	beans	do	
46	8	do	oats	Michigan	129	33	do	oats	do	
47	8	do	beans	do	130	33	do	beans	do	
48	9	do	oats	Missouri	131	35	do	oats	Distr. of Col.	
49	9	do	beans	do	135	45	do	do	Florida	
50	10	do	oats	Montana	139	46	do	do	do	
51	11	do	do	New York	143	47	do	do	do	
52	12	do	do	Oregon	144	48	do	do	do	
55	13	do	do	South Dakota	147	49	do	do	Maryland	
56	13	do	beans	do	148	49	do	beans	do	
58	14	do	oats	Texas	151	36	do	oats	Composit	
59	14	do	beans	do	156	37	do	do	England	
60	15	do	oats	Wisconsin	157	37	do	beans	do	
61	15	do	beans	do	158	38	do	oats	do	
63	17	surface	oats	California	159	38	do	beans	do	
64	17	do	beans	do	160	39	do	oats	do	
65	18	do	oats	do	161	39	do	beans	do	
67	18	do	beans	do	162	40	do	oats	do	
69	19	do	oats	Illinois	163	40	do	beans	do	
70	20	do	do	do	164	41	do	oats	do	
71	20	do	beans	do	165	41	do	beans	do	
73	21	do	oats	Indiana	166	42	do	oats	do	
74	22	do	do	Iowa	167	42	do	beans	do	
75	22	do	beans	do	168	43	do	oats	do	
76	23	do	oats	Kansas	169	43	do	beans	do	
77	23	do	beans	do	170	44	do	oats	do	
					171	44	do	beans	do	

Table 3.-- Total crop yields of oats and buckwheat grown in succession on virgin soils.

(a = surface soil; b = subsoil.)

Pot No:	Soil No:	1895		1896		1897		1898		1899		1900		1901		1902	
		Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat
		grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams
1	1(a	a	a	49.5	32.6	31.0	19.2	26.2	16.1	29.5	9.8	84.6	23.7	41.6	5.3	26.8	1.3
31	1(b	a		34.7	19.5	18.5	20.1	21.1	9.8	20.7	8.5	73.0	( )	29.7	5.0	b	b
3	2(a	27.8		35.8	8.5	21.2	6.8	22.5	3.5	16.7	15.0	67.7	7.1	43.7	0.2	65.9	2.9
33	2(b	15.1		8.5	1.1	6.9	1.2	11.7	0.4	6.4	0.1	2.3	0.4	40.2	0.2	75.5	5.0
5	3(a	51.4		29.8	25.0	30.0	14.8	16.8	4.5	17.3	16.0	47.6	8.2	41.3	3.2	67.9	6.8
35	3(b	13.4		8.1	5.9	6.3	5.9	5.4	1.5	6.9	0.8	30.1	12.3	72.8	17.4	37.3	5.8
9	4(a	c35.1		23.9	30.0	18.3	26.8	21.0	11.8	21.2	3.8	56.6	( )	64.1	2.9	34.8	0.5
38	4(b	c16.9		12.1	13.3	11.4	7.5	12.8	3.9	4.0	0.8	21.9	8.1	35.2	2.5	b	b
10	5(a	c30.7		46.0	46.3	42.2	38.2	35.4	16.0	38.8	14.6	71.2	32.3	70.0	16.7	b	b
39	5(b	c14.5		31.6	17.8	18.9	27.8	22.4	14.7	26.8	5.7	81.1	20.3	49.7	6.1	36.9	4.1
7	6(a	66.4		40.2	24.8	37.6	24.0	23.4	7.6	18.6	13.0	81.8	11.5	69.8	2.0	60.9	5.7
41	6(b	20.9		9.0	10.5	12.7	11.4	10.0	3.3	8.6	1.4	49.4	12.3	69.0	17.7	b	b
12	7(a	d20.8		30.8	17.7	19.5	6.9	22.0	2.1	13.8	15.0	1.1	5.9	19.9	0.8	55.5	5.0
44	7(b	12.7		6.8	6.1	5.0	5.7	7.3	5.1	4.7	2.6	0.4	2.3	25.5	1.1	b	b
14	8(a	e40.3		47.2	37.3	23.6	21.2	28.1	5.5	28.7	4.2	40.1	15.8	43.8	6.9	45.5	3.3
46	8(b	d 9.0		12.7	7.6	8.8	8.7	9.0	3.1	6.6	2.3	23.5	4.4	51.6	16.6	b	b
16	9(a	56.1		47.8	38.6	26.3	28.2	19.6	7.4	34.3	2.0	64.7	3.7	41.0	1.5	47.3	5.3
48	9(b	d 9.0		12.4	4.6	9.3	6.6	12.7	1.0	13.2	0.5	30.1	1.9	37.3	0.4	58.3	3.9

Table 3.-- Continued:

18	10(a	:a	:a	: 51.1	:36.8	: 31.0	: 27.3	: 32.0	: 13.4	: 34.9	: 14.9	: 79.9	: 27.3	: 29.5	: 15.7	: 17.4	: 2.9 :
50	10(b	:a	:	: 2.4	: 7.4	: 9.3	: 9.0	: 7.7	: 2.4	: 8.8	: 0.1	: ( )	: 2.9	: 18.3	: 1.6	:b	:b :
19	11(a	:a	:	: 52.1	:44.6	: 29.3	: 38.8	: 12.2	: 17.2	: 17.2	: 11.6	: 93.1	: 30.7	: 52.5	: 14.1	: 39.2	: 6.0 :
51	11(b	: 65.7	:	: ( )	:13.3	: 8.6	: 12.4	: 6.3	: 6.1	: 8.8	: 3.1	: 26.3	: 12.0	: 35.3	: 10.3	: 55.3	: 3.1 :
20	12(a	:a	:	: 19.4	:25.6	: 23.3	: 17.9	: 20.1	: 14.4	: 18.9	: 3.1	: 73.0	: 16.2	: 37.0	: 4.6	:b	:b :
52	12(b	:a	:	: 11.8	: 2.0	: 3.5	: 8.2	: 2.5	: 2.9	: 9.5	: 4.1	: 24.3	: 6.3	: 18.9	: 2.7	:b	:b :
22	13(a	:a	:	: 45.0	:31.7	: 36.9	: 29.9	: 24.9	: 12.1	: 25.6	: 5.3	: 75.5	: 19.9	: 56.0	: 3.0	: 36.2	: 0.6 :
55	13(b	:a	:	: 16.7	:10.8	: 8.7	: 8.3	: 11.3	: 3.7	: 13.8	: 2.1	: 13.2	: 9.7	: 8.5	: 3.5	:b	:b :
25	14(a	: 49.1	:	: 28.3	:20.7	: 24.4	: 13.5	: 18.8	: 3.9	: 12.6	: 2.5	: 82.4	: 7.8	: 41.9	: 0.6	: 61.6	: 2.9 :
58	14(b	: 24.7	:	: ( )	: 4.5	: 3.4	: 6.4	: 3.5	: 0.9	: 7.0	: 2.5	: 13.3	: 6.2	: 33.9	: 4.5	:b	:b :
27	15(a	: 74.6	:	: 48.7	:38.1	: 28.6	: 36.0	: 31.8	: 13.1	: 35.7	: 12.8	: 78.6	: 10.9	: 52.2	: 6.9	: 38.6	: 2.1 :
60	15(b	: 20.8	:	: 6.6	:9.7	: 5.1	: 11.4	: 12.0	: 5.8	: 3.9	: 4.7	: 20.6	: 4.4	: 48.2	: 3.4	: 12.8	: 1.3 :
127	16 a	: 14.2	:	: 4.4	: 6.7	: 4.9	: 6.0	: 6.3	: 3.1	: 4.0	: 2.3	: 8.7	: 10.8	: 47.8	: 7.6	: 46.7	: 2.1 :

a Not planted
b Discontinued
c Buckwheat grown
d Beans grown
e Clay pots used




Table 4.-- Total crop yields of beans and buckwheat, grown in succession on virgin soils.
(Cowpeas grown in 1901, 1902).
(a = surface soil; b = subsoil.)

Pot No:	Soil No:	1895		1896		1897		1898		1899		1900		1901	1902
		Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Cow-peas	Buck-wheat	Cowpeas
		grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams
2	1(a	a	a	34.0	27.1	42.1	25.2	26.9	14.3	27.7	6.0	37.8	21.9	99.8	0.7	164.1
32	1(b	a	a	35.9	26.2	43.0	32.7	30.7	14.8	28.8	10.8	40.3	24.8	94.2	1.0	b
4	2(a	24.9	11.7	16.9	19.4	12.2	8.7	9.8	2.4	6.4	10.0	2.1	11.3	.7	0.4	75.7
34	2(b	13.6	a	4.9	8.2	3.8	1.2	5.4	00.5	4.1	0.1	1.3	4.7	1.0	0.3	204.1
6	3(a	62.0	34.6	28.2	24.9	24.4	18.4	17.9	5.1	11.2	28.0	3.0	c47.3	2.6	1.0	247.8
36	3(b	19.7	a	13.5	7.5	12.1	7.5	14.2	4.4	9.9	1.3	2.3	13.5	62.4	0.6	167.0
11	5(a	e30.7	a	39.7	31.1	43.9	35.6	31.9	16.2	32.4	14.6	68.5	35.7	90.5	3.0	b
40	5(b	e14.5	a	21.5	20.7	31.6	29.9	27.1	13.3	20.4	8.5	33.0	22.3	74.9	0.7	131.6
8	6(a	e38.1	a	30.1	33.7	34.5	34.4	23.7	11.0	16.8	4.7	4.2	4.3	2.3	5.0	289.5
42	6(b	e15.4	a	12.4	8.3	16.4	12.3	12.8	2.9	8.5	2.3	2.5	12.5	3.1	1.5	b
13	7(a	e20.8	a	21.0	22.7	14.2	11.7	11.7	3.2	6.0	1.2	1.0	2.0	2.4	1.0	175.4
45	7(b	e13.5	a	9.5	6.3	19.4	10.8	9.4	8.4	11.3	3.3	1.2	4.9	38.8	0.8	b
15	8(a	e49.7	a	35.5	33.9	29.6	34.1	23.6	12.5	25.4	6.4	32.0	33.1	54.2	0.5	123.3
47	8(b	e 9.0	a	17.0	13.6	19.4	12.6	18.0	6.0	17.7	2.3	14.3	9.4	77.6	1.5	b
17	9(a	e24.2	a	29.8	38.6	31.8	27.5	20.6	10.8	12.7	2.8	3.0	1.6	27.8	6.8	207.7
49	9(b	9.0	a	14.0	12.4	8.7	5.7	9.9	1.3	7.0	( )	1.0	3.6	1.8	0.5	140.7
21	12(a	a	a	21.1	21.0	30.4	28.1	25.9	13.1	23.1	14.1	33.2	( )	92.9	0.7	b
--	12(															

Table 4.-- Continued

23	13 (a	a	a	29.7	35.4	28.7	31.3	31.6	17.1	20.9	11.3	26.9	23.9	53.0	0.6	99.6
56	(b	a	a	15.2	12.6	16.4	11.3	21.6	6.5	20.5	1.9	11.3	14.6	9.0	6.1	b
26	14 (a	e 28.6	a	27.3	23.1	29.2	19.5	19.3	5.6	10.0	2.0	7.9	3.8	0.9	0.6	130.6
59	(b	e 20.0	a	10.5	3.1	6.9	4.7	6.6	2.0	6.1	3.8	1.3	( )	45.5	9.6	b
28	15 (a	e 42.8	a	33.1	41.4	34.0	47.5	42.0	14.5	33.4	10.0	24.3	3.4	68.7	1.3	151.9
61	(b	e 14.7	a	17.7	13.2	29.0	20.4	15.5	10.6	14.4	4.6	3.0	12.8	100.4	0.5	205.1
128	16 a	21.6	a	14.1	8.0	15.6	12.3	20.7	4.3	13.8	2.9	2.1	13.3	59.5	1.9	93.5

a Not planted
b Discontinued
c Cowpeas
d Buckwheat grown
e Crops grown in clay pots

Table 5.--- Comparison of total crop yields of oats and beans grown on the same virgin soils. (Cowpeas grown instead of beans in 1901, 1902.)

(a = surface soil; b = subsoil.)

Pot No.	Soil No.	1895		1896		1897		1898		1899		1900		1901		1902	
		Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Cow-peas	Oats	Cow-peas
		grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams
1- 2	1(a	a	a	49.5	34.0	31.0	42.1	26.2	26.9	29.5	27.7	84.6	37.8	41.6	99.8	26.8	164.1
31-32	1(b	a	a	34.7	35.9	18.5	43.0	21.1	30.7	20.7	28.8	73.0	40.3	29.7	94.2	b	b
3- 4	2(a	27.8	24.9	35.8	16.9	21.2	12.2	22.5	9.8	16.7	6.4	67.7	2.1	43.7	.7	65.9	75.7
33-34	2(b	15.1	13.6	8.5	4.9	6.9	3.8	11.7	5.4	6.4	4.1	2.3	1.3	40.2	1.0	75.5	204.1
5- 6	3(a	51.4	62.0	29.8	28.2	30.0	24.4	16.8	17.9	17.3	11.2	47.6	3.0	41.3	2.6	67.9	247.8
35-36	3(b	13.4	19.7	8.1	13.5	6.3	12.1	5.4	14.2	6.9	9.9	30.1	2.3	72.8	62.4	37.3	167.0
10-11	5(a	[c]( )	a	46.0	39.7	42.2	43.9	35.4	31.9	38.8	32.4	71.2	68.5	70.0	90.5	b	b
39-40	5(b	[c]14.5	a	31.6	21.5	18.9	31.6	22.4	27.1	26.8	20.4	81.1	33.0	49.7	74.9	36.9	131.6
7- 8	6(a	66.4	a	40.2	30.1	37.6	34.5	23.4	23.7	18.6	16.8	81.8	4.2	69.8	2.3	60.9	289.5
41-42	6(b	20.9	a	9.0	12.4	12.7	16.4	10.0	12.8	8.6	8.5	49.4	2.5	69.0	3.1	b	b
12-13	7(a	[d]20.8	a	30.8	21.0	19.5	14.2	22.0	11.7	13.8	6.0	1.1	1.0	19.9	2.4	55.5	175.4
44-45	7(b	12.7	a	6.8	9.5	5.0	19.4	7.3	9.4	4.7	11.3	0.4	1.2	25.5	38.8	b	b
14-15	8(a	[c]40.3	a	47.2	35.5	23.6	29.6	28.1	23.6	28.7	25.4	40.1	32.0	43.8	54.2	45.5	123.3
46-47	8(b	[d] 9.0	a	12.7	17.0	8.8	19.4	9.0	18.0	6.6	17.7	23.5	14.3	51.6	77.6	b	b
16-17	9(a	[d]56.1	a	47.8	29.8	26.3	31.8	19.6	20.6	34.3	12.7	64.7	3.0	41.0	27.8	47.3	207.7
48-49	9(b	[d] 9.0	a	12.4	14.0	9.3	8.7	12.7	9.9	13.2	7.0	30.1	1.0	37.3	1.8	58.3	140.7
20-21	12(a	a	a	19.4	21.1	23.3	30.4	20.1	25.9	18.9	23.1	73.0	33.2	37.0	92.9	b	b
52-53	12(b	a	a	11.8	( )	3.5	17.8	2.5	14.4	9.5	11.0	24.3	2.3	18.9	41.2	b	b

Table 5.--- Continued

22-23	13(a	:a	:a	: 45.0:	29.7:	36.9:	28.7:	24.9:	31.6:	25.6:	20.9:	75.5:	26.9:	56.0:	53.0:	36.2:	99.6:
55-56	13(b	:a	:a	: 16.7:	15.2:	8.7:	16.4:	11.3:	21.6:	13.8:	20.5:	13.2:	11.3:	8.5:	9.0:	b	:b :
25-26	14(a	: 49.1:	a	: 28.3:	27.3:	24.4:	29.2:	18.8:	19.3:	12.6:	10.0:	82.4:	7.9:	41.9:	0.9:	61.6:	130.6:
58-59	14(b	: 24.7:	a	: ( ):	10.5:	3.4:	6.9:	3.5:	6.6:	7.0:	6.1:	13.3:	1.3:	33.9:	( ):	b	:b :
27-28	15(a	: 74.6:	a	: 48.7:	33.1:	28.6:	34.0:	31.8:	42.0:	35.7:	33.4:	78.6:	24.3:	52.2:	68.7:	38.6:	151.9:
60-61	15(b	: 20.8:	a	: 6.6:	17.7:	5.1:	29.0:	12.0:	15.5:	3.9:	14.4:	20.6:	3.0:	48.2:	100.4:	42.8:	205.1:

a Not planted
b Discontinued
c Buckwheat grown
d Beans grown
e Clay pots used.

Table 6.-- Nitrogen, potash, and phosphoric acid content of total crops of oats and buckwheat, grown in succession on virgin soils.

(a = surface soil; b = subsoil.)

Pot	Soil No		1895		1896		1897		1898		1899		1900		1901		1902	
			Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat
			Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
1	1 a	(N	a	a	1.13	1.33	1.36	1.73	1.41	2.52	1.58	2.17	1.32	1.85	.83	1.99	1.00	( )
		(K_2O	a	a	3.75	3.60	3.64	4.21	3.83	3.73	4.81	2.70	3.53	3.85	3.76	2.41	2.61	( )
		(P_2O_5	a	a	.97	1.23	1.31	1.71	1.21	1.10	1.13	.84	1.37	2.00	1.53	1.29	1.12	( )
31	1 b	(N	a	a	.83	1.50	1.05	1.62	1.48	2.59	1.60	1.97	1.35	( )	.83	( )	b	b
		(K_2O	a	a	3.18	3.16	3.46	2.93	3.76	4.20	2.89	2.74	3.39	( )	3.05	( )	b	b
		(P_2O_5	a	a	1.26	1.23	1.92	1.85	1.51	1.56	1.10	.98	1.86	( )	2.16	( )	b	b
3	2 a	(N	.80	a	1.17	2.37	1.14	2.24	1.27	2.68	1.70	( )	1.84	2.58	1.96	( )	1.68	3.60
		(K_2O	3.24	a	2.87	2.70	3.36	2.66	3.38	3.38	3.23	3.46	2.55	1.64	1.29	( )	.68	1.42
		(P_2O_5	.33	a	.34	.34	.38	.27	.34	.44	.28	.49	.40	.64	.49	( )	.41	1.27
33	2 b	(N	1.33	a	.95	( )	1.21	( )	1.57	( )	( )	( )	1.70	3.90	1.58	( )	1.41	3.00
		(K_2O	2.75	a	2.29	( )	2.78	3.38	2.33	1.98	2.34	( )	2.64	( )	1.46	( )	1.66	2.21
		(P_2O_5	.47	a	.33	( )	.42	.43	.50	.48	.23	( )	( )	( )	.81	( )	.42	1.07
5	3 a	(N	1.47	a	1.51	1.84	1.54	2.36	2.33	2.39	1.67	( )	2.00	2.16	1.30	2.04	1.63	3.38
		(K_2O	3.14	a	3.41	3.00	2.93	3.20	3.84	3.88	3.65	2.77	3.40	1.86	2.80	1.59	1.36	1.82
		(P_2O_5	.34	a	.29	.40	.42	.37	.49	.44	.25	.22	.43	.71	.34	.37	.50	1.08
35	3 b	(N	1.64	a	1.61	2.08	1.52	2.05	1.96	2.30	1.75	( )	1.77	2.25	1.02	1.48	1.10	2.53
		(K_2O	3.14	a	2.53	2.49	3.03	2.32	3.99	2.42	3.23	2.64	3.35	1.82	3.21	1.99	2.53	2.79
		(P_2O_5	.32	a	.36	.31	.29	.29	.25	.21	.41	.18	.48	.53	.41	.89	.97	1.36

Table 6.-- Continued

	(N	[c]1.63	a	1.53	1.38	1.25	1.84	1.88	2.33	1.58	2.23	2.08	2.66	1.68	2.38	1.10	( )	
9	4 a(K2O	2.51	a	2.82	3.29	1.62	2.85	2.06	2.97	1.89	2.35	1.83	1.50	( )	( )	1.63	( )	
	(P2O5	.41	a	.36	.39	.37	1.16	.42	.80	.27	.52	.71	.80	1.18	( )	1.51	( )	
	(N	[c]1.66	a	1.18	1.48	1.31	1.69	1.33	( )	1.17	( )	1.37	1.97	1.05	2.02	b	b	
38	4 b(K2O	2.56	a	2.39	2.63	2.54	2.62	3.11	2.70	2.81	2.46	2.84	2.02	3.08	( )	b	b	
	(P2O5	.27	a	.45	.30	.57	.80	.40	.32	.28	.32	.54	.74	1.57	( )	b	b	
	(N	[c]1.39	a	1.29	1.49	1.34	2.09	1.48	2.49	2.00	2.50	2.42	2.20	1.24	1.79	b	b	
10	5 a(K2O	2.41	a	2.55	2.23	2.14	2.15	1.37	2.20	1.30	1.79	1.65	1.87	1.21	1.25	b	b	
	(P2O5	.79	a	.74	.60	.86	.74	.51	.76	.24	.72	.59	1.65	.40	.88	b	b	
	(N	[c]1.29	a	.94	1.76	1.22	1.55	1.10	2.01	1.17	2.20	1.79	2.06	.86	1.96	1.17	3.38	
39	5b (K2O	2.50	a	2.55	2.55	1.97	2.47	1.66	2.61	1.45	2.17	1.47	1.40	1.57	1.39	1.28	1.47	
	(P2O5	.53	a	.45	.51	.80	.60	.53	.58	.53	.75	.49	1.51	.48	.93	.56	.98	
	(N	1.95	a	1.30	2.13	1.43	2.05	2.16	2.68	2.10	( )	2.14	1.64	1.40	1.85	1.56	3.30	
7	6 a(K2O	3.93	a	3.26	3.25	3.84	3.17	4.09	3.41	3.79	3.20	3.68	2.32	2.74	( )	1.85	2.16	
	(P2O5	.35	a	.42	.31	.30	.21	.47	.63	.28	.49	.49	1.10	( )	( )	.57	1.54	
	(N	1.64	a	1.56	1.69	1.61	1.85	2.10	2.14	( )	( )	2.06	1.95	1.27	1.88	b	b	
41	6 b(K2O	3.93	a	2.21	2.54	3.50	2.20	3.64	2.35	3.13	2.27	3.70	2.23	3.49	1.83	b	b	
	(P2O5	.39	a	.25	.33	.34	.26	.29	.21	.38	.25	.31	.67	.41	.80	b	b	
	(N	[d]2.03	a	1.23	1.76	1.22	1.78	1.71	2.36	1.63	( )	( )	2.70	2.08	( )	1.75	3.27	
12	7 a[d](K2O	1.90	a	1.85	2.49	1.47	1.23	1.31	2.34	1.66	1.34	( )	1.81	2.98	( )	2.68	2.81	
	(P2O5	.68	a	.48	.40	.62	.29	.40	( )	.34	.28	( )	.66	.31	( )	.29	.64	
	(N	1.13	a	.98	1.53	1.06	1.42	1.04	1.99	.88	1.76	( )	2.55	1.42	( )	b	b	
44	7 b(K2O	.98	a	1.59	2.51	1.80	2.65	1.91	1.99	1.37	2.42	( )	1.35	2.44	( )	b	b	
	(P2O5	.47	a	.72	.42	.73	.45	.62	.41	.35	.40	( )	.59	.36	( )	b	b	

Table 6.-- Continued

		(N	1.15	a	( )	1.49	1.08	2.15	1.45	2.98	2.00	2.20	2.14	1.90	1.50	2.04	1.40	3.85
14	8a[e]	(K_2O	2.70	a	( )	( )	2.46	2.03	1.74	2.38	1.72	2.55	( )	1.40	1.02	1.21	.92	1.08
		(P_2O_5	.46	a	( )	.52	.48	.56	.43	.54	.25	.47	( )	.93	1.49	1.06	.60	1.81
		(N	2.52	a	1.14	1.48	1.22	1.54	1.25	2.07	( )	( )	1.30	1.38	.90	1.71	b	b
46	8 b[d]	(K_2O	2.85	a	2.60	2.75	3.00	2.36	3.40	2.48	3.10	2.50	3.01	2.35	2.48	1.51	b	b
		(P_2O_5	.43	a	.48	.40	.40	.22	.33	.19	.35	.25	.47	.48	1.16	1.05	b	b
		(N	1.54	a	1.23	1.55	1.01	2.15	1.85	2.63	1.80	2.58	2.12	2.70	1.45	( )	1.86	2.71
16	9 a	(K_2O	2.32	a	2.24	2.63	2.33	2.53	1.54	2.58	1.67	3.21	1.64	1.23	1.64	( )	1.58	1.28
		(P_2O_5	.37	a	.22	.41	.40	.42	.44	.54	.42	.40	.22	.88	.28	( )	.43	.60
		(N	2.17	a	.94	1.33	1.21	1.93	1.06	( )	( )	( )	1.18	2.12	.86	( )	1.15	3.30
48	9 b[d]	(K_2O	2.76	a	2.66	2.30	2.67	2.07	2.71	2.22	2.82	( )	3.21	1.91	1.91	( )	1.80	2.18
		(P_2O_5	.46	a	.43	.20	.50	.24	.34	.29	.42	( )	.54	.85	1.01	( )	.51	1.60
		(N	a	a	1.19	1.36	1.14	2.09	1.10	2.43	1.63	2.30	1.43	1.56	.90	1.74	1.10	3.00
18	10 a	(K_2O	a	a	3.72	3.77	3.96	3.84	4.22	4.37	3.64	1.44	4.54	3.21	3.75	2.41	2.28	2.96
		(P_2O_5	a	a	.69	.76	.89	1.03	.78	.61	.64	.27	.64	1.44	.90	.97	.92	.75
		(N	a	a	1.69	2.89	1.27	1.46	1.55	2.06	( )	( )	1.14	1.70	.71	( )	b	b
50	10 b	(K_2O	a	a	2.09	1.99	1.41	2.48	1.77	2.60	1.56	( )	1.34	2.23	2.96	( )	b	b
		(P_2O_5	a	a	.69	.48	.49	.24	.63	.27	.64	( )	( )	.43	.45	( )	b	b
		(N	a	a	1.37	1.61	1.58	1.78	2.16	2.37	2.60	2.00	1.76	1.86	.90	1.68	1.33	3.40
19	11 a	(K_2O	a	a	4.20	3.73	3.63	3.15	3.59	3.66	3.80	2.67	2.93	2.12	2.44	2.04	1.85	2.36
		(P_2O_5	a	a	.94	1.22	1.23	.96	.59	.80	.59	.82	1.31	1.70	1.42	1.07	1.08	1.56
		(N	.92	a	( )	1.50	1.40	1.48	1.83	1.79	1.91	2.15	1.24	1.88	.92	2.13	1.17	2.50
51	11 b	(K_2O	3.13	a	( )	2.88	.90	2.12	1.99	2.93	1.56	2.64	2.72	2.34	2.24	1.28	1.61	1.81
		(P_2O_5	.48	a	( )	1.23	.65	.72	.69	.88	.64	.94	2.13	1.73	.89	1.04	.76	1.47

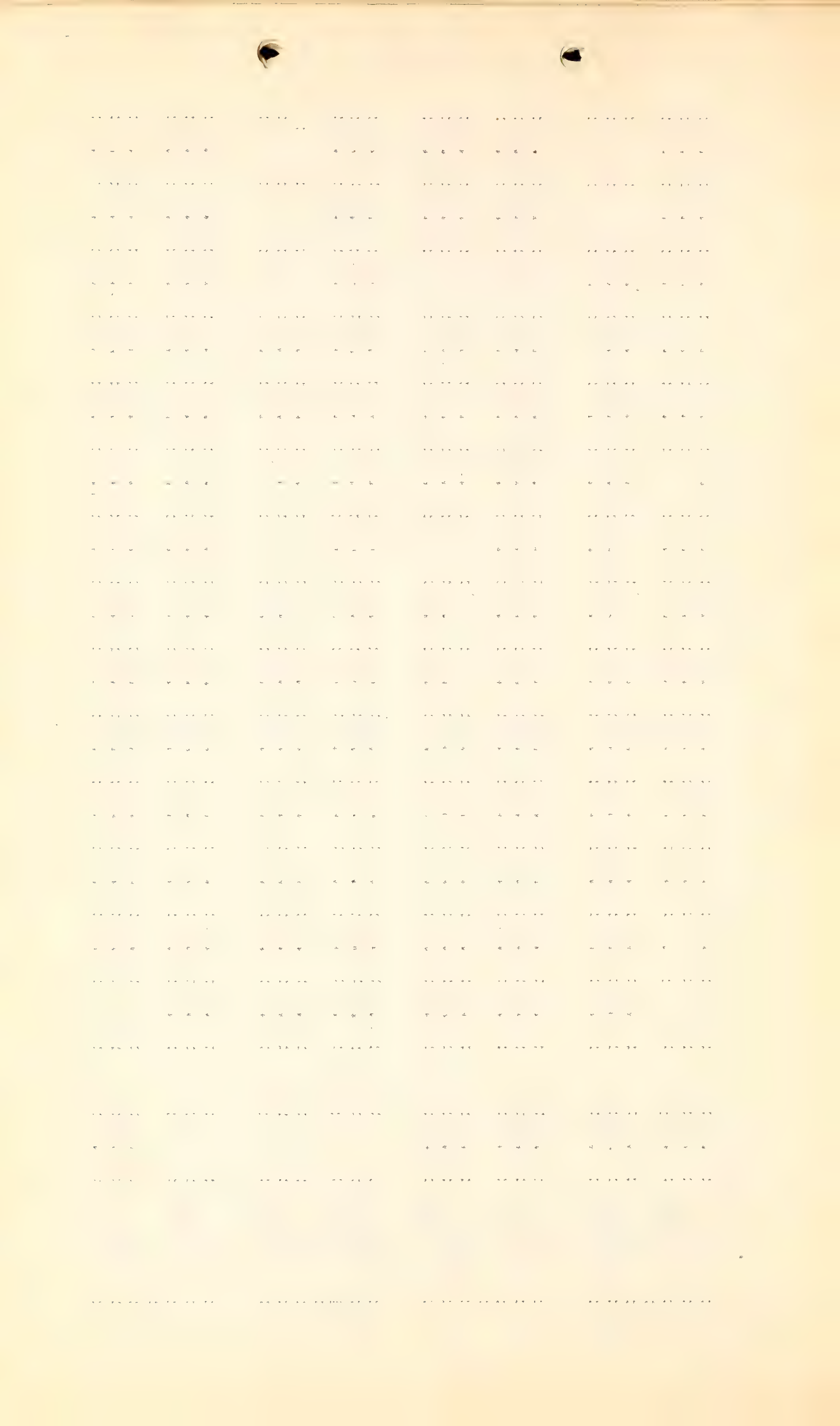


Table 6.--Continued

	(N	a	a	1.38	1.43	1.02	2.17	1.26	2.33	1.35	2.35	1.30	1.85	.78	1.96	b	b	
20	12 a(K_2O	a	a	3.03	3.15	1.64	3.03	2.40	2.18	2.14	3.78	2.48	1.41	2.72	1.55	b	b	
	(P_2O_5	a	a	1.50	1.22	1.00	1.15	1.33	.72	1.21	.65	.45	1.40	1.76	.99	b	b	
	(N	a	a	.91	1.98	1.19	1.48	2.38	2.21	( )	( )	1.21	1.80	.93	1.96	b	b	
52	12 b(K_2O	a	a	2.06	2.86	3.11	2.68	4.98	3.08	2.91	2.38	2.87	2.22	3.09	2.84	b	b	
	(P_2O_5	a	a	.36	.36	.49	.37	.46	.36	.40	.35	.47	.50	.70	.58	b	b	
	(N	a	a	1.19	1.59	1.23	2.08	1.00	2.38	1.35	2.42	1.94	2.50	1.28	2.16	1.10	( )	
22	13 a(K_2O	a	a	3.41	2.59	3.38	3.07	3.10	3.51	2.56	3.05	1.87	2.02	1.96	1.96	1.75	( )	
	(P_2O_5	a	a	.28	.34	.25	.41	.31	.40	.44	.50	1.13	1.06	.39	.43	.47	) (	
	(N	a	a	1.23	1.54	1.13	1.62	1.34	2.07	1.00	( )	1.94	1.54	1.80	1.90	b	b	
55	13 b(K_2O	a	a	2.95	1.87	3.05	1.75	3.15	2.10	2.89	1.58	2.69	1.98	3.03	1.35	b	b	
	(P_2O_5	a	a	.30	.26	.40	.25	.31	.18	.33	.38	.25	.52	.50	.50	b	b	
	(N	1.23	a	1.16	1.60	1.04	2.09	1.12	2.37	1.18	( )	1.68	2.00	1.44	( )	1.54	3.60	
25	14 a(K_2O	2.46	a	2.86	2.82	2.25	2.62	2.17	2.53	2.09	2.21	1.49	1.51	1.25	( )	.70	1.00	
	(P_2O_5	.30	a	.36	.32	.37	.32	.42	.38	.48	.38	.45	.85	.46	( )	.42	1.69	
	(N	1.46	a	( )	1.52	.85	1.48	1.89	( )	( )	( )	1.66	1.68	1.15	2.07	b	b	
58	14 b(K_2O	2.30	a	( )	3.23	2.28	2.60	4.24	2.85	2.69	2.47	( )	2.50	2.37	2.59	b	b	
	(P_2O_5	.29	a	( )	.28	.25	.29	.28	.29	.46	.17	.28	.37	.47	1.04	b	b	
	(N	1.53	a	1.22	1.37	1.48	1.54	1.60	2.50	1.53	2.32	1.76	2.42	.98	2.13	2.38	3.50	
27	15 a(K_2O	2.41	a	2.03	2.40	1.90	1.48	1.59	1.54	3.70	1.42	1.28	1.26	1.07	1.09	1.18	1.14	
	(P_2O_5	.66	a	1.00	1.15	1.22	.87	1.19	.78	1.02	.79	1.20	2.03	.87	1.20	.67	1.25	
	(N	.95	a	1.22	1.54	1.28	1.47	1.04	1.79	( )	( )	1.03	1.45	.89	2.16	1.15	( )	
60	15 b(K_2O	2.42	a	1.68	2.88	2.74	3.07	3.14	2.98	2.86	2.83	2.09	2.87	3.31	2.74	2.59	( )	
	(P_2O_5	1.36	a	1.67	1.19	1.14	1.30	2.35	.81	.26	1.21	1.17	1.73	1.25	.62	.49	( )	

Table 6.-- Continued

	(N	1.06	a	.94	1.45	.98	1.54	1.11	1.94	( )	( )	1.85	1.65	.96	2.04	.98	2.26
127	16 a(K_2O	2.86	a	1.88	2.67	2.68	2.63	2.89	2.76	2.87	2.75	2.80	2.49	3.34	1.87	2.35	3.47
	(P_2O_5	.47	a	.45	.36	.52	.28	.55	.36	.30	.29	.36	.58	.65	.61	.57	.79

a Not planted
b Discontinued
c Buckwheat grown
d Beans grown
e Clay pots used

Table 7.-- Nitrogen, potash, and phosphoric acid content of total crops of beans and buckwheat grown in succession on virgin soils. (Cowpeas grown instead of beans in 1901, 1902.)

(a = surface soil; b = subsoil.)

Pot	Soil No		1895		18962		1897		1898		1899		1900		1901		1902	
			Beans	Buckwheat	Beans	Buckwheat	Beans	Buckwheat	Beans	Buckwheat	Beans	Buckwheat	Beans	Buckwheat	Cowpeas	Buckwheat	Cowpeas	
			Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
2	1 a	(N	a	a	2.42	1.76	2.61	1.39	2,84	2.69	( )	( )	3.32	2.12	3.66	a	1.48	
		(K_2O	a	a	2.85	4.54	2.19	4.44	3.12	3.84	3.63	2.21	2.10	3.50	2.35	a	.76	
		(P_2O_5	a	a	.72	1.04	.70	1.27	1.31	1.08	.98	1.02	1.16	1.61	1.04	a	.28	
32	1 b	(N	a	a	2.09	1.34	2.43	1.42	2.57	2.08	( )	( )	2.68	1.66	3.27	a	b	
		(K_2O	a	a	2.43	3.45	2.16	3.13	2.80	3.75	2.81	3.08	1.91	2.86	2.15	a	b	
		(P_2O_5	a	a	.81	1.17	.76	1.10	.97	1.43	.92	1.14	1.27	1.76	.93	a	b	
4	2 a	(N	1.87	1.72	2.96	1.71	3.46	2.31	4.48	2.80	( )	( )	6.12	6.60	( )	( )	1.58	
		(K_2O	2.97	2.67	2.90	3.03	3.67	2.81	3.88	2.94	3.82	3.66	3.48	2.68	( )	( )	1.66	
		(P_2O_5	.65	.22	.62	.20	.61	.27	.67	.50	.58	.47	.60	.62	( )	( )	.48	
34	2 b	(N	2.66	a	3.06	2.30	3.44	( )	( )	( )	( )	( )	( )	2.60	4.75	( )	2.37	
		(K_2O	3.45	a	3.59	3.32	4.18	2.92	3.33	2.30	3.39	( )	( )	2.35	( )	( )	.88	
		(P_2O_5	.67	a	.50	.31	.55	.66	.84	.30	.77	( )	( )	.58	( )	( )	.41	
6	3 a	(N	2.18	1.74	2.60	1.44	2.71	2.33	4.24	2.49	( )	( )	2.80	2.84	3.64	( )	1.25	
		(K_2O	3.06	2.92	2.63	3.27	2.46	3.11	3.41	2.87	3.84	3.15	2.74	2.95	( )	( )	1.14	
		(P_2O_5	.44	.37	.47	.33	.54	.24	.62	.50	.55	.46	.38	.76	.36	( )	.35	
36	3 b	(N	2.84	a	2.90	1.97	2.50	2.09	3.95	2.14	( )	( )	( )	2.24	2.78	( )	1.41	
		(K_2O	2.36	a	3.26	2.51	3.58	2.28	4.06	2.65	4.07	2.56	2.82	2.42	2.39	( )	.66	
		(P_2O_5	.39	a	.28	.28	.32	1.12	.80	.85	.50	.27	.13	.72	.53	( )	.30	

Table 7.-- Continued

	(N	[c]1.39	a	2.38	1.48	2.42	1.73	2.72	2.84	( )	( )	3.21	3.00	3.14	3.02	b	
11	5 a(K_2O	2.41	a	2.16	3.15	1.27	2.20	1.95	2.50	1.73	2.00	1.04	1.62	.90	( )	b	
	(P_2O_5	.79	a	.84	.48	.65	.75	.91	.75	.95	.75	.64	1.65	.63	( )	b	
	(N	[c]1.29	a	2.53	1.55	2.61	1.57	2.75	2.00	( )	( )	3.71	2.10	2.70	( )	1.58	
40	5b (K_2O	2.50	a	2.18	2.93	1.46	2.71	1.97	2.73	1.71	2.14	1.55	1.92	1.18	( )	.50	
	(P_2O_5	.53	a	.71	.56	.63	.53	.93	.60	.63	.56	.56	1.55	.53	( )	.26	
	(N	[c]2.02	a	2.71	1.74	1.25	2.30	3.84	2.78	( )	( )	( )	3.23	4.21	3.51	2.36	
8	6 a(K_2O	2.96	a	2.67	3.09	2.36	3.35	3.56	3.54	3.89	2.89	2.84	2.37	( )	( )	1.76	
	(P_2O_5	.37	a	.56	.34	.45	.48	.69	.66	.66	.76	.75	2.25	( )	( )	.33	
	(N	[d]2.85	a	2.64	1.94	2.80	1.91	4.25	1.90	( )	( )	( )	2.10	3.35	( )	b	
42	6 b(K_2O	2.73	a	3.24	2.67	3.10	2.54	4.17	2.88	3.94	4.55	( )	2.25	( )	( )	b	
	(P_2O_5	.38	a	.32	.29	.41	.26	.50	.23	.53	.32	( )	.71	( )	( )	b	
	(N	[d]2.03	a	2.12	1.79	2.65	2.12	3.96	2.52	( )	( )	( )	3.60	3.86	( )	2.45	
13	7 a(K_2O	1.90	a	1.73	2.32	1.79	2.03	2.20	2.97	2.05	2.02	( )	2.90	( )	( )	1.16	
	(P_2O_5	.68	a	.63	.39	.65	.29	.52	.42	.59	.38	( )	.81	( )	( )	.34	
	(N	[d]2.43	a	2.35	1.41	( )	1.32	3.35	1.85	( )	( )	( )	2.58	2.37	( )	b	
45	7 b(K_2O	1.80	a	1.62	2.35	( )	2.14	2.17	1.86	2.25	2.74	( )	1.24	1.77	( )	b	
	(P_2O_5	.72	a	.64	.41	( )	.47	.64	.35	.67	.40	( )	.82	.41	( )	b	
	(N	[d]2.74	a	( )	1.44	2.55	2.14	2.90	2.16	( )	( )	3.15	2.04	3.24	( )	2.14	
15	8 a(K_2O	2.21	a	( )	2.89	1.55	2.39	1.63	2.77	1.76	4.31	1.34	1.33	.60	( )	.60	
	(P_2O_5	.37	a	( )	.48	.55	.51	.55	.55	.74	.58	.52	.91	.73	( )	.37	
	(N	[c]2.52	a	2.43	1.42	( )	1.61	2.45	1.72	( )	( )	2.56	1.60	3.50	( )	b	
47	8 b(K_2O	2.85	a	2.56	2.74	( )	1.02	2.68	2.59	2.82	2.35	2.88	2.44	1.80	( )	b	
	(P_2O_5	.43	a	.54	.36	( )	.28	.51	.27	.46	.21	.25	.62	.60	( )	b	

Table 7.-- Continued

	(N	[c]2.07	a	2.51	1.60	2.53	2.39	3.99	2.48	( )	( )	( )	3.20	2.92	2.74	1.76	
17	9 a(K_2O	2.11	a	2.14	2.83	1.63	2.73	2.09	2.81	2.42	1.80	2.10	2.21	3.83	1.56	.95	
	(P_2O_5	.55	a	.43	.38	.58	.48	1.07	.48	.63	.33	.33	1.66	.48	.96	.21	
	(N	2.17	a	2.69	1.47	2.82	2.07	4.55	2.57	( )	( )	( )	2.56	3.10	( )	2.27	
49	9 b(K_2O	2.76	a	3.33	2.44	3.72	2.51	4.31	2.60	4.19	( )	3.50	.85	( )	( )	1.47	
	(P_2O_5	.46	a	.62	.26	.56	.26	.69	.09	.70	( )	.71	.31	( )	( )	.36	
	(N	a	a	2.68	1.37	2.41	1.57	2.74	2.09	( )	( )	3.17	2.22	3.66	( )	b	
21	12 a(K_2O	a	a	2.04	3.55	1.29	2.58	1.82	2.70	1.85	1.86	1.36	( )	1.03	( )	b	
	(P_2O_5	a	a	.92	1.09	.71	.71	.90	.58	.84	.69	.68	( )	.65	( )	b	
--	(N																
	12 b(K_2O																
	(P_2O_5																
	(N	a	a	2.84	1.56	2.20	1.95	2.69	2.16	( )	( )	4.42	2.48	2.64	( )	1.55	
23	13 a(K_2O	a	a	2.35	2.84	2.15	2.66	2.58	3.20	3.23	2.84	2.43	2.21	1.49	( )	.52	
	(P_2O_5	a	a	.47	.32	.40	.40	.72	.37	.80	.59	.51	1.51	.23	( )	.16	
	(N	a	a	2.38	1.33	2.28	1.63	2.44	2.10	( )	( )	3.89	1.70	2.87	1.68	b	
56	13 b(K_2O	a	a	3.19	2.26	2.25	1.87	2.86	2.22	2.71	1.86	2.71	2.05	( )	1.24	b	
	(P_2O_5	a	a	.36	.20	.32	.18	.47	.29	.46	.15	.06	.57	( )	.41	b	
	(N	1.57	a	2.27	1.43	2.40	2.08	2.94	2.45	( )	( )	5.36	2.75	3.95	( )	2.43	
26	14 a(K_2O	2.19	a	2.62	2.86	1.18	2.53	2.33	2.49	2.52	1.54	2.97	1.18	( )	( )	.45	
	(P_2O_5	.45	a	.63	.37	.48	.32	.64	.39	.67	.33	.54	.93	( )	( )	.32	
	(N	2.31	a	2.28	1.45	2.64	1.57	3.08	2.29	( )	( )	( )	2.86	2.40	1.88	b	
59	14 b(K_2O	2.16	a	3.22	3.11	3.92	2.87	4.45	3.25	4.38	3.03	( )	( )	( )	1.68	b	
	(P_2O_5	.47	a	.49	.31	.49	.31	.71	.23	.67	.40	( )	( )	( )	1.11	b	

Table 7.-- Continued

		(N	2.08	a	2.26	1.46	1.47	1.88	2.73	2.52	( )	( )	4.18	3.05	2.75	( )	1.10	
28	15	a (K_2O	2.20	a	1.73	2.57	1.09	1.74	1.63	1.76	1.78	1.75	1.60	1.77	.77	( )	.56	
		(P_2O_5	.81	a	.69	.95	.79	1.06	.89	.88	1.15	.84	.72	2.33	.72	( )	.41	
		(N	1.82	a	2.61	1.33	2.64	1.32	2.83	1.73	( )	( )	4.42	2.32	3.04	( )	2.44	
61	15	b (K_2O	2.59	a	2.49	3.13	1.93	2.89	2.88	3.18	3.16	2.38	2.91	2.54	1.66	( )	1.21	
		(P_2O_5	.62	a	.98	1.17	.75	.84	1.05	.97	.90	.61	1.24	1.66	.53	( )	.47	
		(N	1.66	a	2.38	1.48	2.42	1.61	2.16	2.02	( )	( )	( )	1.51	2.68	( )	1.82	
128	13	a (K_2O	2.73	a	2.78	2.98	2.36	2.47	3.10	1.83	3.56	2.55	3.92	2.21	2.37	( )	.86	
		(P_2O_5	.61	a	.44	.39	.66	.38	.47	.33	.54	.17	.24	.48	.31	( )	.29	

a Not planted
b Discontinued
c Buckwheat grown
d Crops grown in clay pots

Table 8.-- Comparison of nitrogen, potash, and phosphoric acid content of total crops of oats and beans grown on the same virgin soils. (Cowpeas grown in place of beans in 1901, 1902.)

(a = surface soil; b = subsoil.)

Pot No:	Soil No		1895		1896		1897		1898		1899		1900		1901		1902	
			Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Cow-peas	Oats	Cow-peas
			Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
		(N	a	a	1.13	2.42	1.36	2.61	1.41	2.84	1.58	( )	1.32	3.32	.83	3.66	1.00	1.48
1-- 2:	1 a	(K_2O	a	a	3.75	2.85	3.64	2.19	3.83	3.12	4.81	3.63	3.53	2.10	3.76	2.35	2.61	.76
		(P_2O_5	a	a	.97	.72	1.31	.70	1.21	1.31	1.13	.98	1.37	1.16	1.53	1.04	1.12	.28
		(N	a	a	.83	2.09	1.05	2.43	1.48	2.57	1.60	( )	1.35	2.68	.83	3.27	b	b
31--32:	1 b	(K_2O	a	a	3.18	2.43	3.46	2.16	3.76	2.80	2.89	2.81	3.39	1.91	3.05	2.15	b	b
		(P_2O_5	a	a	1.26	.81	1.92	.76	1.51	.97	1.10	.92	1.86	1.27	2.16	.93	b	b
		(N	.80	1.87	1.17	2.96	1.14	3.46	1.27	4.48	1.70	( )	1.84	6.12	1.96	( )	1.68	1.58
3-- 4:	2 a	(K_2O	3.24	2.97	2.87	2.90	3.36	3.67	3.38	3.88	3.23	3.82	2.55	3.48	1.29	( )	.68	1.66
		(P_2O_5	.33	.65	.34	.62	.38	.61	.34	.67	.28	.58	.40	.60	.49	( )	.41	.48
		(N	1.33	2.66	.95	3.06	1.21	3.44	1.57	( )	( )	( )	1.70	( )	1.58	4.75	1.41	2.37
33--34:	2 b	(K_2O	2.75	3.45	2.29	3.59	2.78	4.18	2.33	3.33	2.34	3.39	2.64	( )	1.46	( )	1.66	.88
		(P_2O_5	.47	.67	.33	.50	.42	.55	.50	.84	.23	.77	( )	( )	.81	( )	.42	.41
		(N	1.47	2.18	1.51	2.60	1.54	2.71	2.33	4.24	1.67	( )	2.00	2.80	1.30	3.64	1.63	1.25
5-- 6:	3 a	(K_2O	3.14	3.06	3.41	2.63	2.93	2.46	3.84	3.41	3.65	3.84	3.40	2.74	2.80	( )	1.36	1.14
		(P_2O_5	.34	.44	.29	.47	.42	.54	.49	.62	.23	.55	.43	.38	.34	.36	.50	.35
		(N	1.64	2.84	1.61	2.90	1.52	2.50	1.96	3.95	1.75	( )	1.77	( )	1.02	2.78	1.10	1.41
35--36:	3 b	(K_2O	3.14	2.36	2.53	3.26	3.03	3.58	3.99	4.06	3.23	4.07	3.35	2.32	3.21	2.39	2.53	.66
		(P_2O_5	.32	.39	.36	.28	.29	.32	.25	.80	.41	.50	.48	.13	.41	.53	.97	.30

Table 8.-- Continued

10--11	5 a	(N	[c]( )	[c]( )	1.29	2.38	1.34	2.42	1.48	2.72	2.00	( )	2.42	3.21	1.24	3.14	[b]	[b]
		(K_2O	( )	( )	2.55	2.16	2.14	1.27	1.37	1.95	1.30	1.73	1.65	1.04	1.21	.90	[b]	[b]
		(P_2O_5	( )	( )	.74	.84	.86	.65	.51	.91	.24	.95	.59	.64	.40	.63	[b]	[b]
39--40	5 b	(N	[c]( )	( )	.94	2.53	1.22	2.61	1.10	2.75	1.17	( )	1.79	3.71	.86	2.70	1.17	1.58
		(K_2O	( )	( )	2.55	2.18	1.97	1.46	1.66	1.97	1.45	1.71	1.47	1.55	1.57	1.18	1.28	.50
		(P_2O_5	( )	( )	.45	.71	.80	.63	.53	.93	.53	.63	.49	.56	.48	.53	.56	.26
7-- 8	6a	(N	1.95	[c]2.02	1.30	2.71	1.43	1.25	2.16	3.84	2.10	( )	2.14	( )	1.40	4.21	1.56	2.36
		(K_2O	3.93	2.96	3.26	2.67	3.84	2.36	4.09	3.56	3.79	3.89	3.68	2.84	2.74	( )	1.85	1.76
		(P_2O_5	.35	.37	.42	.56	.30	.45	.47	.69	.28	.66	.49	.75	( )	( )	.57	.33
41--42	6 b	(N	1.64	[c]2.85	1.56	2.64	1.61	2.80	2.10	4.25	( )	( )	2.06	( )	1.27	3.35	[b]	[b]
		(K_2O	3.93	2.73	2.21	3.24	3.50	3.10	3.64	4.17	3.13	3.94	3.70	( )	3.49	( )	[b]	[b]
		(P_2O_5	.39	.38	.25	.32	.34	.41	.29	.50	.38	.53	.31	( )	.41	( )	[b]	[b]
12--13	7 a	(N	[d]( )	( )	1.23	2.12	1.22	2.65	1.71	3.96	1.63	( )	( )	( )	2.08	3.86	1.75	2.45
		(K_2O	( )	( )	1.85	1.73	1.47	1.79	1.31	2.20	1.66	2.05	( )	( )	2.98	( )	2.68	1.16
		(P_2O_5	( )	( )	.48	.63	.62	.65	.40	.52	.34	.59	( )	( )	.31	( )	.29	.34
44--45	7 b	(N	1.13	[e]2.43	.98	2.35	1.06	( )	1.04	3.35	.88	( )	( )	( )	1.42	2.37	[b]	[b]
		(K_2O	.98	1.80	1.59	1.62	1.80	( )	1.91	2.17	1.37	2.25	( )	( )	2.44	1.77	[b]	[b]
		(P_2O_5	.47	.72	.72	.64	.73	( )	.62	.64	.35	.67	( )	( )	.36	.41	[b]	[b]
14--15	8 a	(N	1.15	[e]2.74	( )	( )	1.08	2.55	1.45	2.90	2.00	( )	2.14	3.15	1.50	3.24	1.40	2.14
		(K_2O	2.70	2.21	( )	( )	2.46	1.55	1.74	1.63	1.72	1.76	( )	1.34	1.02	.60	.92	.60
		(P_2O_5	.46	.37	( )	( )	.48	.55	.43	.55	.25	.74	( )	.52	1.49	.73	.60	.37
46--47	8 b	(N	[d]( )	[c]( )	1.14	2.43	1.22	( )	1.25	2.45	( )	( )	1.30	2.56	.90	3.50	[b]	[b]
		(K_2O	( )	( )	2.60	2.56	3.00	( )	3.40	2.68	3.10	3.82	3.01	2.88	2.48	1.80	[b]	[b]
		(P_2O_5	( )	( )	.48	.54	.40	( )	.33	.51	.35	.46	.47	.25	1.16	.60	[b]	[b]

Table 8.-- Continued

16--17	9 a	(N	1.54	c2.07	1.23	2.51	1.01	2.53	1.85	3.99	1.80	( )	2.12	( )	1.45	2.92	1.86	1.76
		(K_2O	2.32	2.11	2.24	2.14	2.33	1.63	1.54	2.09	1.67	2.42	1.64	2.10	1.64	3.83	1.58	.95
		(P_2O_5	.37	.55	.22	.43	.40	.58	.44	1.07	.42	.63	.22	.33	.28	.48	.43	.21
48--49	9 b	(N	2.17	2.17	.94	2.69	1.21	2.82	1.06	4.55	( )	( )	1.18	( )	.86	3.10	1.15	2.27
		(K_2O	2.76	2.76	2.66	3.33	2.67	3.72	2.71	4.31	2.82	4.19	3.21	3.50	1.91	( )	1.80	1.47
		(P_2O_5	.46	.46	.43	.62	.50	.56	.34	.69	.42	.70	.54	.71	1.01	( )	.51	.36
20--21	12 a	(N	a	a	1.38	2.68	1.02	2.41	1.26	2.74	1.35	( )	1.30	3.17	.78	3.66	b	b
		(K_2O	a	a	3.03	2.04	1.64	1.29	2.40	1.82	2.14	1.85	2.48	1.36	2.72	1.03	b	b
		(P_2O_5	a	a	1.50	.92	1.00	.71	1.33	.90	1.21	.84	.45	.68	1.76	.65	b	b
52--53	12 b	(N	a	a	.91	2.39	1.19	2.21	2.38	2.41	( )	( )	1.21	( )	.93	2.54	b	b
		(K_2O	a	a	2.06	2.08	3.11	1.83	4.98	2.66	2.91	2.84	2.87	3.17	3.09	3.24	b	b
		(P_2O_5	a	a	.36	.51	.49	.51	.46	.71	.40	.50	.47	.53	.70	.59	b	b
22--23	13 a	(N	a	a	1.19	2.84	1.23	2.20	1.00	2.69	1.35	( )	1.94	4.42	1.28	2.64	1.10	1.55
		(K_2O	a	a	3.41	2.35	3.38	2.15	3.10	2.58	2.56	3.23	1.87	2.43	1.96	1.49	1.75	.52
		(P_2O_5	a	a	.28	.47	.25	.40	.31	.72	.44	.80	1.13	.51	.39	.43	.47	.16
55--56	13 b	(N	a	a	1.23	2.38	1.13	2.28	1.34	2.44	1.00	( )	1.94	3.89	1.30	2.87	b	b
		(K_2O	a	a	2.95	3.19	3.05	2.25	3.15	2.86	2.89	2.71	2.69	2.71	3.03	( )	b	b
		(P_2O_5	a	a	.30	.36	.40	.32	.31	.47	.33	.46	.25	.06	.50	( )	b	b
25--26	14 a	(N	1.23	1.57	1.16	2.27	1.04	2.40	1.12	2.94	1.18	( )	1.68	5.36	1.44	3.95	1.54	2.43
		(K_2O	2.46	2.19	2.86	2.62	2.25	1.18	2.17	2.33	2.09	2.52	1.49	2.97	1.25	( )	.70	.45
		(P_2O_5	.30	.45	.36	.63	.37	.48	.42	.64	.48	.67	.45	.54	.46	( )	.42	.32
58--59	14 b	(N	1.46	2.31	( )	2.28	.85	2.64	1.89	3.08	( )	( )	1.66	( )	1.15	2.40	b	b
		(K_2O	2.30	2.16	( )	3.22	2.28	3.92	4.24	4.45	2.69	4.38	( )	( )	2.37	( )	b	b
		(P_2O_5	.29	.47	( )	.49	.25	.49	.28	.71	.46	.67	.28	( )	.47	( )	b	b

Table 8.-- Continued

27--28	15 a	(N	1.53	2.08	1.22	2.26	1.48	1.47	1.60	2.73	1.53	( )	1.76	4.18	.98	2.75	2.38	1.10
		(K_2O	2.41	2.20	2.03	1.73	1.90	1.09	1.59	1.63	3.70	1.78	1.28	1.60	1.07	.77	1.18	.56
		(P_2O_5	.66	.81	1.00	.69	1.22	.79	1.19	.89	1.02	1.15	1.20	.72	.87	.72	.67	.41
60--61	15 b	(N	.95	1.82	1.22	2.61	1.28	2.64	1.04	2.83	( )	( )	1.03	4.42	.89	3.04	1.15	2.44
		(K_2O	2.42	2.59	1.68	2.49	2.74	1.93	3.14	2.88	2.86	3.16	2.09	2.91	3.31	1.66	2.59	1.21
		(P_2O_5	1.36	.62	1.67	.98	1.14	.75	2.35	1.05	.26	.90	1.17	1.24	1.25	.53	.49	.47

a Not planted
b Discontinued
c Buckwheat grown
d Beans grown
e Clay pots used.

Table 9.-- Parts per million of nitrogen, potash, and phosphoric acid taken from virgin soils by total crops of oats and buckwheat grown in succession.

(a = surface soil; b = subsoil.)

Pot	Soil No		1895		1896		1897		1898		1899		1900		1901		1902	
			Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat
1	1 a	(N	a	a	18	13	14	10	11	13	14	7	41	16	13	4	10	( )
		(K_2O	a	a	60	36	36	25	31	19	43	8	109	33	57	5	26	( )
		(P_2O_5	a	a	16	12	10	10	10	6	10	3	42	17	23	3	11	( )
31	1 b	(N	a	a	11	10	7	13	12	10	13	6	41	( )	10	( )	b	b
		(K_2O	a	a	41	22	24	23	30	17	23	8	101	( )	37	( )	b	b
		(P_2O_5	a	a	16	9	14	15	12	6	9	3	55	( )	26	( )	b	b
3	2a	(N	10	a	18	9	10	7	11	3	12	( )	57	8	39	( )	50	5
		(K_2O	41	a	43	11	30	8	30	3	23	21	78	5	26	( )	20	2
		(P_2O_5	4	a	5	1	3	1	3	1	2	3	12	2	10	( )	12	2
33	2 b	(N	7	a	3	( )	3	( )	7	( )	( )	( )	2	1	25	( )	42	6
		(K_2O	15	a	7	( )	8	2	11	( )	6	( )	2	( )	23	( )	49	4
		(P_2O_5	3	a	1	( )	1	( )	2	( )	1	( )	( )	( )	13	( )	12	2
5	3 a	(N	34	a	18	18	18	14	27	16	12	( )	47	9	26	3	55	11
		(K_2O	72	a	41	30	35	19	25	27	26	19	80	8	57	3	45	6
		(P_2O_5	8	a	3	4	5	2	5	3	2	1	10	3	7	1	17	4
35	3 b	(N	10	a	5	4	5	4	4	2	5	( )	24	13	34	12	19	7
		(K_2O	19	a	8	5	9	5	8	2	10	1	46	10	106	16	43	7
		(P_2O_5	2	a	1	1	1	1	1	( )	1	( )	7	3	14	7	16	4

Table 9.-- Continued

	(N	[c]41:a	23:	26:	15:	31:	24:	19:	22:	11:	80:	( ):	73:	( ):	26:	( ):					
9: 4 a	(K_2O	63:a	42:	63:	19:	48:	27:	24:	26:	12:	70:	( ):	( ):	( ):	39:	( ):					
	(P_2O_5	10:a	5:	7:	4:	20:	5:	6:	4:	3:	27:	( ):	51:	( ):	36:	( ):					
	(N	[c]20:a	6:	9:	7:	6:	7:	( ):	2:	( ):	13:	7:	16:	( ):b		:b					
38: 4 b	(K_2O	31:a	13:	15:	14:	9:	17:	5:	5:	1:	27:	7:	47:	( ):b		:b					
	(P_2O_5	3:a	2:	2:	3:	3:	2:	1:	( ):	( ):	5:	3:	24:	( ):b		:b					
	(N	[c]30:a	28 :	32:	27:	39:	24:	19:	36 :	17:	80:	33:	40:	14:b		:b					
10: 5 a	(K_2O	53:a	55 :	48:	44:	40:	23:	16:	23 :	12:	55:	28:	39:	10:b		:b					
	(P_2O_5	17:a	16 :	13:	18:	14:	8:	6:	4 :	5:	20:	25:	13:	68:b		:b					
	(N	[c]13:a	12:	12:	10:	19:	10:	12:	13:	4:	68:	20:	20:	6:	20:	7:					
39: 5 b	(K_2O	26:a	33:	18:	16:	30:	15:	16:	16:	4:	56:	13:	36:	4:	22:	3:					
	(P_2O_5	5:a	6:	4:	1:	7:	6:	3:	6:	2:	19:	14:	11:	3:	10:	2:					
	(N	60:a	22:	23:	23:	20:	22:	8:	17:	( ):	85:	9:	47:	( ):	46:	9:					
7: 6 a	(K_2O	121:a	98:	36:	61:	32:	41:	10:	30:	19:	146:	13:	92:	( ):	54:	6:					
	(P_2O_5	11:a	7:	3:	5:	2:	5:	2:	2:	3:	19:	6:	( ):	( ):	17:	4:					
	(N	17:a	7:	9:	10:	10:	10:	4:	( ):	( ):	51:	12:	44:	17:b		:b					
41: 6 b	(K_2O	41:a	10:	13:	22:	12:	18:	4:	13:	2:	91:	14:	120:	18:b		:b					
	(P_2O_5	4:a	1:	1:	2:	1:	1:	( ):	2:	( ):	8:	4:	14:	8:b		:b					
	(N	[d]30:a	17:	12:	11:	5:	17:	2:	10:	( ):	( ):	7:	19:	( ):	45:	9:					
12: 7 a	(K_2O	28:a	26:	17:	13:	4:	13:	2:	10:	9:	( ):	4:	27:	( ):	69:	7:					
	(P_2O_5	10:a	7:	3:	6:	1:	4:	( ):	2:	2:	( ):	2:	3:	( ):	7:	1:					
	(N	6:a	3:	4:	2:	4:	3:	5:	2:	2:	( ):	3:	16:	( ):b		:b					
44: 7 b	(K_2O	5:a	5:	7:	4:	7:	6:	5:	3:	3:	( ):	1:	28:	( ):b		:b					
	(P_2O_5	3:a	2:	1:	2:	1:	2:	1:	1:	( ):	( ):	1:	4:	( ):b		:b					

Table 9.-- Continued

	(N		c33	a	( )		19		9		17		14		6		20		3
14:	8 a(K2O		78	a	( )	( )	20		16		17		5		17		5	( )	9
	(P2O5		13	a	( )		7		4		4		4		1		2		1
	(N	d		a			5		4		4		5		4		2	( )	( )
46:	8 b(K2O	( )		a			11		7		9		7		10		3		7
	(P2O5	( )		a			2		1		1		1		1	( )		( )	1
	(N		38	a			20		25		11		26		15		8		25
16:	9 a(K2O		58	a			44		42		37		30		12		8		23
	(P2O5		9	a			4		7		4		5		4		2		6
	(N		14	a			5		2		5		5		6	( )		( )	
48:	9 b(K2O		18	a			13		4		10		6		14		1		16
	(P2O5		3	a			2	( )			2		1		2	( )			2
	(N	a		a			26		22		16		25		15		15		24
18:	10 a(K2O	a		a			82		60		55		46		59		26		55
	(P2O5	a		a			15		12		12		12		11		4		10
	(N	a		a			2		8		5		6		5		2	( )	
50:	10 b(K2O	a		a			2		6		6		10		6		3		6
	(P2O5	a		a			1		1		2		1		2	( )			2
	(N	a		a			25		26		16		25		9		14		16
19:	11 a(K2O	a		a			76		60		36		44		14		22		23
	(P2O5	a		a			17		20		12		13		2		5		4
	(N		21	a	( )		8		4		6		4		4		6		2
51:	11 b(K2O		72	a	( )		14		3		8		4		6		5		3
	(P2O5		11	a	( )		6		2		2		1		2		1		1

	(N		63		22		18		9		20		8						
19:	11 a(K2O		105		35		49		11		28		5						
	(P2O5		47		20		29		6		16		4						
	(N		12		9		12		8		25		3						
51:	11 b(K2O		27		11		30		5		34		2						
	(P2O5		21		8		12		4		16		2						

Table 9.-- Continued

| | | |

Table 9.-- Continued

	(N	6	a	2	4	2	4	3	2	( )	( )	6	7	18	6	18	2
127	16 a(K_2O	16	a	3	7	5	7	7	3	5	2	10	11	64	6	43	3
	(P_2O_5	3	a	1	1	1	1	1	( )	( )	( )	1	3	12	2	10	1

a Not planted
b Discontinued
c Buckwheat grown
d Beans grown

Table 10.-- Parts per million of nitrogen, potash, and phosphoric acid taken from virgin soils by total crops of beans and buckwheat grown in succession.
(Cowpeas grown instead of beans in 1901, 1902.)

(a = surface soil; b = subsoil.)

Pot: Soil No	1895		1896		1897		1898		1899		1900		1901		1902
	Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Cow-peas	Buck-wheat	Cow-peas
(N	a	a	27	15	43	14	30	15	( )	( )	46	18	144	( )	97
2:1 a(K_2O	a	a	31	40	36	44	33	22	40	5	29	30	93	( )	50
(P_2O_5	a	a	8	9	12	13	14	6	11	2	16	14	41	( )	18
(N	a	a	28	13	42	19	32	12	( )	( )	44	17	124	( ) b	
32:1 b(K_2O	a	a	32	33	37	41	34	22	33	13	31	29	82	( ) b	
(P_2O_5	a	a	11	11	13	15	12	9	11	5	21	18	35	( ) b	
(N	21	( )	( )	( )	20	10	21	3	( )	( )	6	35	( )	( )	58
4:2 a(K_2O	33	( )	( )	( )	21	12	8	3	12	17	3	14	( )	( )	60
(P_2O_5	7	( )	( )	( )	4	1	3	1	2	2	1	3	( )	( )	17
(N	16	a	7	8	6	( )	( )	( )	( )	( )	( )	5	2	( )	210
34:2 b(K_2O	21	a	8	12	7	2	8	1	6	( )	( )	5	( )	( )	78
(P_2O_5	4	a	1	1	1	( )	2	( )	1	( )	( )	1	( )	( )	40
(N	60	( )	( )	( )	33	21	39	6	( )	( )	4	67	5	( )	150
6:3 a(K_2O	85	( )	( )	( )	30	28	30	7	21	44	8	69	( )	( )	144
(P_2O_5	12	( )	( )	( )	7	2	6	1	3	6	1	18	( )	( )	48
(N	25	a	18	7	15	8	25	4	( )	( )	( )	14	78	( )	61
36:3 b(K_2O	21	a	20	9	22	9	26	5	18	2	3	15	67	( )	50
(P_2O_5	3	a	2	1	2	4	5	2	2	( )	( )	4	15	( )	23

Table 10.-- Continued

		(N	c30:a	53:	26:	60:	35:	49:	26:	( ):	( ):	124:	40:	160:	( ):b					
11:	5	a(K_2O	53:a	48:	55:	31:	44:	35:	23:	31:	16:	40:	32:	46:	( ):b					
		(P_2O_5	17:a	19:	8:	16:	15:	16:	7:	17:	6:	25:	33:	32:	( ):b					
		(N	c13:a	27:	16:	43:	25:	37:	13:	( ):	( ):	61:	23:	100:	( ):	104:				
40:	5	b(K_2O	26:a	23:	30:	24:	42:	26:	18:	17:	9:	25:	21:	44:	( ):	32:				
		(P_2O_5	5:a	8:	6:	10:	8:	12:	4:	6:	2:	9:	17:	20:	( ):	16:				
		(N	c55:a	38:	27:	22:	40:	42:	14:	( ):	( ):	( ):	6:	4 :	( ):	342:				
8:	6	a(K_2O	81:a	37:	48:	41:	58:	39:	18:	30:	6:	5:	5:	( ):	( ):	232:				
		(P_2O_5	10:a	8:	5:	8:	8:	8:	3:	5 :	2:	1:	4:	( ):	( ):	43:				
		(N	d31:a	16:	8:	24:	12:	27:	3:	( ):	( ):	( ):	13:	5:	( ):b					
42:	6	b(K_2O	30:a	20:	11:	26:	16:	26:	4:	16:	3:	( ):	14:	( ):	( ):b					
		(P_2O_5	4:a	2:	1:	4:	2:	3 :	( ):	2:	( ):	( ):	4:	( ):	( ):b					
		(N	d30:a	19:	18:	18:	12:	22:	4:	( ):	( ):	( ):	5:	4:	( ):	204:				
13:	7	a(K_2O	28:a	16:	23:	12:	11:	12:	4:	6:	1:	( ):	3:	( ):	( ):	97:				
		(P_2O_5	10:a	6:	3:	4:	2:	3:	( ):	2:	( ):	( ):	1:	( ):	( ):	28:				
		(N	d23:a	9:	4:	( ):	7:	13:	6:	( ):	( ):	( ):	5:	38:	( ):b					
45:	7	b(K_2O	17:a	6:	6:	( ):	11:	8:	7:	11:	4:	( ):	2:	20:	( ):b					
		(P_2O_5	7:a	2:	1:	( ):	2:	3:	1:	3:	1:	( ):	2:	7:	( ):b					
		(N	d97:a	( ):	18:	31:	30:	26:	10:	( ):	( ):	38:	25:	66:	( ):	100:				
15:	8	a(K_2O	78:a	( ):	37:	19:	34:	14:	13:	17:	10:	16:	16:	12:	( ):	27:				
		(P_2O_5	13:a	( ):	6:	7:	7:	5:	3:	7:	1:	6:	11:	15:	( ):	17:				
		(N	c16:a	14:	6:	( ):	7:	15:	4:	( ):	( ):	13:	5:	95:	( ):b					
47:	8	b(K_2O	18:a	14:	12:	( ):	4:	17:	5:	17:	2:	14:	8:	49:	( ):b					
		(P_2O_5	3:a	3:	2:	( ):	1:	3:	1:	3:	( ):	1:	2:	16:	( ):b					

Table 10.-- Continued

	(N	[c]36	a	33	27	39	32	45	12	( )	( )	( )	2	36	8	166	
17	9 a	(K_2O	36	a	28	49	25	37	19	16	13	2	3	2	47	5	90	
		(P_2O_5	10	a	5	7	9	6	10	2	3	( )	4	1	6	3	20	
	(N	14	a	15	7	10	5	19	1	( )	( )	( )	4	2	( )	138	
49	9 b	(K_2O	18	a	18	12	14	6	18	1	12	( )	2	1	( )	( )	90	
		(P_2O_5	3	a	3	1	2	1	3	( )	2	( )	( )	( )	( )	( )	22	
	(N	a	a	30	15	42	25	41	16	( )	( )	60	( )	194	( )	b		
21	12 a	(K_2O	a	a	23	40	22	41	27	20	24	15	37	( )	55	( )	b		
		(P_2O_5	a	a	10	12	12	11	13	4	11	6	10	( )	34	( )	b		
	(N																		
--	12 b	(K_2O																	
		(P_2O_5																	
	(N	a	a	33	21	27	26	33	14	( )	( )	41	23	54	( )	60	
23	13 a	(K_2O	a	a	27	39	26	35	32	21	26	12	25	20	32	( )	21	
		(P_2O_5	a	a	5	4	5	5	9	6	6	7	5	14	8	( )	6	
	(N	a	a	11	5	13	7	19	5	( )	( )	16	9	9	4	b		
56	13 b	(K_2O	a	a	14	8	13	8	22	5	20	1	11	11	( )	3	b		
		(P_2O_5	a	a	2	1	2	1	4	1	3	( )	( )	3	( )	1	b		
	(N		32	a	22	12	27	15	21	5	( )	( )	16	4	1	( )	121	
26	14 a	(K_2O	45	a	26	24	13	18	17	5	10	1	9	2	( )	( )	22	
		(P_2O_5	9	a	6	3	5	2	5	1	3	( )	2	1	( )	( )	16	
	(N		33	a	11	2	9	4	10	2	( )	( )	( )	( )	53	( )	b		
59	14 b	(K_2O	31	a	16	4	13	7	14	3	13	6	( )	( )	( )	8	b		
		(P_2O_5	7	a	2	( )	2	1	2	( )	2	1	( )	( )	( )	5	b		

Table 10.-- Continued

	(N	64	a	33	26	22	39	50	16	( )	( )	44	4	82	( )	153
28:15	a(K_2O	67	a	25	46	16	36	30	11	26	8	17	3	23	( )	37
	(P_2O_5	25	a	10	17	12	22	16	6	17	4	8	3	22	( )	27
	(N	19	a	17	6	31	11	16	7	( )	( )	5	11	113	( )	110
61:15	b(K_2O	27	a	16	15	22	24	17	12	17	4	3	12	62	( )	92
	(P_2O_5	7	a	6	6	9	6	6	4	5	1	1	8	20	( )	35
	(N	14	a	13	5	16	8	17	3	( )	( )	( )	8	63	( )	67
128:16	a(K_2O	23	a	15	9	12	13	25	3	19	3	3	12	55	( )	32
	(P_2O_5	5	a	2	1	4	2	4	1	3	( )	( )	3	7	( )	11

a Not planted
b Discontinued
c Buckwheat grown
d Crops grown in clay pots

Table 11.-- Comparison of the number of parts per million of nitrogen, potash, and phosphoric acid taken from the same virgin soils by total crops of oats and beans.
(Cowpeas grown instead of beans in 1901, 1902.)

(a = surface soil; b = subsoil.)

Pot	Soil No		1895		1896		1897		1898		1899		1900		1901		1902	
			Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Cow-peas	Oats	Cow-peas
1-- 2	1 a	(N	a	a	19	27	15	43	14	30	17	( )	41	46	13	144	10	97
		(K_2O	a	a	62	31	41	36	37	33	52	40	109	29	57	93	26	50
		(P_2O_5	a	a	16	8	15	12	12	14	12	11	42	16	23	41	11	18
31--32	1 b	(N	a	a	11	28	8	42	13	32	13	( )	41	44	10	124 b	b	
		(K_2O	a	a	41	32	26	37	32	34	24	33	101	31	37	82 b	b	
		(P_2O_5	a	a	16	11	7	13	13	12	9	11	55	21	26	35 b	b	
3-- 4	2 a	(N	10	21	18	23	10	20	11	21	12	( )	57	6	39	( )	50	58
		(K_2O	41	33	43	23	30	21	30	8	23	12	78	3	26	( )	20	60
		(P_2O_5	4	7	5	5	3	4	3	3	2	2	12	1	10	( )	12	17
33--34	2 b	(N	7	16	3	7	3	6	7	( )	( )	( )	2	( )	25	2	42	210
		(K_2O	15	21	7	8	8	7	11	8	6	6	2	( )	23	( )	49	78
		(P_2O_5	3	4	1	1	1	1	2	2	1	1	( )	( )	13	( )	12	40
5-- 6	3 a	(N	34	60	18	33	18	33	27	39	12	( )	47	4	26	5	55	150
		(K_2O	72	85	41	33	35	30	25	30	26	21	80	8	57	( )	45	144
		(P_2O_5	8	12	3	6	5	7	5	6	2	3	10	1	7	( )	17	48
35--36	3 b	(N	10	25	6	18	5	15	5	27	5	( )	24	( )	34	78	19	61
		(K_2O	19	21	9	20	10	22	10	26	10	18	46	3	106	67	43	80
		(P_2O_5	2	3	1	2	1	2	1	5	1	2	7	( )	14	15	16	23

Table 11.-- Continued

10--11:	4 a	(N	a	a	28:	53:	27:	60:	24:	49:	36:	( ):	80:	124:	40:	160:	b	b	
		(K_2O	a	a	55:	48:	44:	31:	23:	35:	23:	31:	55:	40:	39:	46:	b	b	
		(P_2O_5	a	a	16:	19:	18:	16:	8:	16:	4:	17:	20:	25:	13:	32:	b	b	
39--40:	4 b	(N	a	a	13:	27:	11:	43:	12:	37:	15:	( ):	68:	61:	20:	100:	20:	104:	
		(K_2O	a	a	36:	23:	17:	24:	17:	26:	18:	17:	56:	25:	36:	40:	22:	32:	
		(P_2O_5	a	a	6:	8:	7:	10:	6:	12:	7:	6:	19:	9:	11:	20:	10:	16:	
7-- 8:	6 a	(N		60:	55:	24:	38:	26:	22:	28:	42:	19:	( ):	85:	( ):	47:	4:	46:	342:
		(K_2O		121:	81:	61:	37:	52:	41:	46:	39:	34:	30:	146:	5:	92:	( ):	54:	232:
		(P_2O_5		11:	10:	8:	8:	5:	8:	5:	8:	3:	5:	19:	1:	( ):	( ):	17:	43:
41--42:	6 b	(N		17:	31:	7:	16:	10:	24:	10:	27:	( ):	( ):	51:	( ):	44:	5:	b	b
		(K_2O		41:	30:	10:	20:	22:	27:	18:	36:	13:	16:	91:	( ):	120:	( ):	b	b
		(P_2O_5		4:	4:	1:	2:	2:	4:	1:	3:	2:	2:	8:	( ):	14:	( ):	b	b
12--13:	7 a	(N		38:	30:	17:	19:	11:	18:	18:	22:	10:	( ):	( ):	( ):	19:	4:	45:	204:
		(K_2O		20:	28:	26:	16:	13:	12:	13:	12:	11:	6:	( ):	( ):	27:	( ):	69:	97:
		(P_2O_5		10:	10:	7:	6:	6:	4:	4:	3:	2:	2:	( ):	( ):	3:	( ):	7:	28:
44--45:	7 b	(N		6:	23:	3:	9:	2:	( ):	3:	13:	2:	( ):	( ):	( ):	16:	38:	b	b
		(K_2O		5:	17:	5:	6:	4:	( ):	6:	8:	5:	11:	( ):	( ):	28:	29:	b	b
		(P_2O_5		3:	7:	2:	3:	2:	( ):	2:	3:	1:	3:	( ):	( ):	4:	7:	b	b
14--15:	8 a	(N		33:	97:	( ):	( ):	10:	31:	16:	26:	22:	( ):	33:	38:	25:	66:	25:	100:
		(K_2O		78:	78:	( ):	( ):	22:	19:	19:	14:	19:	17:	( ):	16:	17:	12:	16:	27:
		(P_2O_5		13:	13:	( ):	( ):	4:	7:	5:	5:	3:	7:	( ):	6:	25:	15:	11:	17:
46--47:	8 b	(N	a	a	5:	14:	4:	( ):	4:	15:	( ):	( ):	( ):	13:	10:	98:	b	b	
		(K_2O	a	a	11:	14:	9:	( ):	10:	17:	7:	15:	7:	14:	24:	49:	b	b	
		(P_2O_5	a	a	2:	3:	1:	( ):	1:	3:	1:	3:	1:	1:	4:	16:	b	b	

Table 11.-- Continued

		(N	38:	36:	26:	33:	12:	39:	17:	37:	29:	( ):	64:	( ):	28:	36:	41:	166:
16--17:	9 a	(K_2O	59:	36:	47:	28:	29:	25:	14:	19:	27:	14:	49:	3:	31:	47:	35:	90:
		(P_2O_5	9:	10:	5:	5:	5:	9:	4:	10:	7:	4:	7:	4:	5:	6:	9:	20:
		(N	14:	14:	5:	15:	5:	10:	5:	19:	( ):	( ):	15:	( ):	13:	2:	28:	138:
48--49:	9 b	(K_2O	18:	18:	13:	18:	10:	14:	14:	18:	15:	12:	40:	2:	30:	( ):	44:	90:
		(P_2O_5	3:	3:	2:	3:	2:	2:	2:	3:	2:	2:	7:	( ):	16:	( ):	12:	22:
		(N	:a	:a	12:	30:	11:	42:	12:	40:	12:	( ):	45:	60:	14:	194:b	:	1:
20--21:	12 a	(K_2O	:a	:a	26:	23:	18:	22:	23:	27:	19:	24:	85:	37:	47:	55:b	:	1:
		(P_2O_5	:a	:a	13:	10:	11:	12:	13:	13:	11:	11:	15:	10:	31:	34:b	:	1:
		(N	:a	:a	5:	12:	2:	12:	3:	14:	( ):	( ):	13:	( ):	8:	42:b	:	:
52--53:	12 b	(K_2O	:a	:a	11:	10:	5:	13:	5:	16:	12:	13:	30:	3:	26:	54:b	:b	:
		(P_2O_5	:a	:a	2:	3:	1:	4:	1:	4:	2:	2:	5:	1:	6:	10:b	:b	:
		(N	:a	:a	21:	33:	19:	27:	10:	33:	14:	( ):	61:	41:	30:	54:	17:	60:
22--23:	13 a	(K_2O	:a	:a	60:	27:	52:	26:	32:	32:	27:	26:	59:	25:	46:	32:	27:	21:
		(P_2O_5	:a	:a	5:	5:	3:	5:	3:	9:	5:	6:	36:	5:	9:	8:	7:	6:
		(N	:a	:a	7:	11:	4:	13:	5:	19:	5:	( ):	9:	16:	6:	9:b	:b	:
55--56:	13 b	(K_2O	:a	:a	16:	14:	10:	13:	13:	22:	14:	20:	13:	11:	9:	( ):b	:b	:
		(P_2O_5	:a	:a	2:	2:	1:	2:	1:	4:	2:	4:	1:	( ):	2:	( ):b	:b	:
		(N	22:	32:	12:	22:	10:	27:	8:	21:	6:	( ):	55:	16:	24:	1;	38:	121:
25--26:	14 a	(K_2O	44:	45:	30:	26:	22:	13:	16:	17:	11:	10:	49:	19:	21:	( ):	17:	22:
		(P_2O_5	5:	9:	4:	6:	4:	5:	3:	5:	2:	3:	15:	2:	8:	( ):	10:	16:
		(N	16:	33:	( ):	11:	1:	9:	3:	10:	( ):	( ):	10:	( ):	20:	53:b	:b	:
58--59:	14 b	(K_2O	25:	31:	( ):	16:	3:	13:	6:	14:	8:	13:	( ):	( ):	41:	( ):b	:b	:
		(P_2O_5	3:	7:	( ):	2:	( ):	2:	( ):	2:	1:	2:	1:	( ):	8:	( ):b	:b	:

Table 11.-- Continued

	(N	43:	64:	22:	33:	17:	22:	20:	50:	22:	( ):	55:	44:	20:	82:	37:	153:
27--28:	15 a(K$_2$O	67:	67:	37:	25:	22:	16:	20:	30:	53:	26:	40:	17:	22:	23:	18:	37:
	(P$_2$O$_5$	18:	25:	18:	10:	3:	12:	15:	16:	15:	17:	38:	8:	18:	22:	10:	27:
	(N	7:	19:	3:	17:	3:	31:	5:	16:	( ):	( ):	8:	5:	17:	113:	19:	110:
60--61:	15 b(K$_2$O	18:	27:	4:	16:	5:	22:	15:	17:	4:	17:	17:	3:	63:	62:	43:	92:
	(P$_2$O$_5$	10:	7:	4:	6:	2:	9:	11:	6:	( ):	5:	9:	1:	24:	20:	8:	35:

a Not planted
b Discontinued

Table 12.-- Total crop yields of oats and buckwheat grown in succession on cultivated soils.

(a = surface soil; b = subsoil.)

Pot No	Soil No	1895		1896		1897		1898		1899		1900		1901		1902	
		Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat
		grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams
63	17(a	( )	a	47.7	20.7	19.3	19.7	15.7	11.4	19.8	6.9	73.5	13.1	18.2	8.8	13.9	10.5
93	17(b	( )	a	28.1	9.0	7.9	14.3	8.2	8.1	7.9	3.9	51.8	9.9	10.5	5.4	( )	( )
65	18(a	59.1	a	14.5	14.5	25.2	14.0	24.0	0.7	29.4	0.2	56.3	1.1	52.4	0.2	24.4	( )
95	18(b	29.5	a	7.8	5.7	9.9	6.7	10.1	2.1	10.0	1.5	24.5	3.3	24.3	7.4	18.8	1.1
69	19(a	[b]13.7	a	30.1	13.2	20.9	13.2	24.1	4.6	19.2	1.3	76.5	5.9	43.8	0.5	49.1	5.2
101	19(b	[c]11.6	a	9.5	2.2	8.5	3.3	13.0	1.0	9.5	0.1	42.7	( )	59.2	13.8	41.2	3.3
70	20(a	45.0	a	( )	24.0	23.0	22.6	16.0	14.7	8.9	8.5	66.3	30.0	59.3	2.1	25.7	2.3
98	20(b	22.3	a	7.1	( )	4.2	8.2	6.3	3.0	3.8	2.7	27.6	6.2	29.4	8.2	29.8	1.3
73	21(a	[d]34.3	a	27.1	34.2	23.2	21.1	22.6	5.5	16.4	1.9	49.1	8.6	52.9	2.3	51.1	2.3
102	21(b	[d] 9.5	a	11.1	7.7	6.9	5.8	8.9	1.8	2.9	1.0	31.6	7.9	42.2	1.2	( )	( )
74	22(a	[d]36.1	a	41.1	40.9	34.8	32.7	30.7	11.8	18.4	5.2	67.5	8.9	79.9	5.0	55.1	1.9
103	22(b	[d]16.7	a	10.7	9.5	13.3	13.2	7.8	6.2	15.1	3.3	55.5	15.8	31.8	5.5	( )	( )
76	23(a	[c]46.2	a	61.4	54.8	49.1	36.9	43.6	13.1	48.6	6.6	88.8	16.7	83.1	4.0	( )	( )
104	23(b	[c]32.3	a	32.5	13.4	15.2	13.6	5.4	4.5	9.0	0.9	68.9	11.8	45.4	1.1	22.7	( )
106	24(a	32.7	a	31.0	22.6	13.7	14.1	12.2	3.2	10.9	2.0	5.2	1.0	39.6	1.0	( )	( )
78	24(b	[c]10.7	a	1.9	4.2	2.9	6.2	6.1	5.9	2.7	1.1	( )	8.8	27.1	5.6	39.4	0.8
80	25(a	27.9	a	48.8	40.4	34.4	26.6	33.1	5.2	27.8	1.4	38.5	15.7	63.2	5.8	48.2	1.3
108	25(b	9.1	a	11.7	9.5	6.6	7.0	9.8	4.5	6.3	2.4	28.1	8.9	43.5	6.6	( )	( )

Table 12.-- Continued

82	26	(a	[b]36.4	a	63.5	46.0	41.0	27.0	34.9	9.6	32.6	9.1	76.1	18.7	43.0	8.8	( )	( )
109		(b	35.8	a	14.3	5.8	8.0	4.5	9.7	1.6	12.4	0.5	36.5	3.5	25.6	0.5	( )	( )
84	27	(a	( )	a	36.9	26.9	22.3	24.0	22.1	12.7	14.1	5.6	75.7	13.4	26.0	4.0	12.5	1.9
111		(b	( )	a	8.9	7.6	5.5	3.7	9.9	1.2	8.2	0.7	21.6	5.6	16.9	2.5	( )	( )
85	28	(a	( )	a	21.1	39.6	20.3	38.0	17.0	10.2	19.2	3.0	85.8	7.7	60.3	1.1	48.3	1.3
112		(b	33.4	a	6.5	6.4	4.1	12.5	3.3	5.1	1.6	4.9	28.7	6.0	35.2	1.7	( )	( )
86	29	(a	( )	a	65.3	40.3	32.7	30.5	32.5	17.5	40.3	3.9	84.0	10.8	57.1	2.2	( )	( )
113		(b	( )	a	46.6	9.3	12.5	13.0	11.7	2.7	15.8	0.3	57.5	2.4	28.6	0.6	( )	( )
87	30	(a	( )	a	44.0	35.8	24.8	24.6	22.3	14.2	21.2	10.2	88.1	28.0	40.6	12.4	20.0	3.0
118		(b	( )	a	16.3	9.6	23.6	5.0	22.1	1.6	10.4	1.0	19.6	12.1	69.8	6.6	( )	( )
89	31	(a	[c]55.1	a	29.7	20.3	26.3	21.3	16.4	2.1	12.7	1.8	58.7	2.6	40.2	0.3	46.6	0.6
120		(b	[c]29.9	a	8.9	4.6	3.7	7.9	8.8	5.1	4.9	1.2	23.0	1.7	38.7	8.7	( )	( )
90	32	(a	59.8	a	35.1	39.5	29.1	35.3	35.3	16.0	25.1	14.3	85.2	26.2	36.5	15.9	37.1	3.1
121		(b	38.7	a	7.4	8.9	5.2	8.8	6.9	5.1	5.4	4.4	32.9	7.8	38.8	1.5	( )	( )
129	33a		26.1	a	14.3	14.6	8.8	12.7	10.4	5.1	13.2	3.2	50.1	5.9	47.9	0.3	64.6	1.9
29	34a		21.5	a	28.7	13.3	19.2	4.0	22.6	0.8	19.7	0.5	35.7	( )	53.2	13.8	48.4	1.8
131	35a		[b]65.9	a	49.6	45.3	31.0	28.1	25.4	8.1	20.5	5.1	58.5	19.0	45.1	8.2	13.3	0.5
151	36a		( )	a	( )	( )	23.1	( )	21.7	4.1	19.1	2.8	60.7	21.7	40.8	9.3	( )	( )
156	37a		( )	a	( )	( )	17.8	23.5	24.5	3.3	30.2	1.7	55.5	8.0	14.0	( )	24.4	1.4

Table 12-- Continued

158	38a	( )	a	( )	( )	34.1	30.2	28.2	6.4	48.9	5.0	74.7	6.1	52.7	5.8	55.0	1.0
160	39a	( )	a	( )	( )	20.1	18.4	24.6	3.7	33.1	1.1	52.2	10.1	30.2	7.2	34.9	0.9
162	40a	( )	a	( )	( )	39.1	39.4	36.8	10.6	56.7	9.5	104.7	16.4	75.8	22.0	56.2	7.2
164	41a	( )	a	( )	( )	29.6	28.5	28.7	7.0	38.0	4.8	64.3	8.1	44.9	( )	48.6	2.1
166	42a	( )	a	( )	( )	22.4	26.8	35.6	7.3	33.1	1.5	48.7	14.2	32.8	8.9	56.5	3.3
168	43a	( )	a	( )	( )	38.9	34.7	32.6	16.3	45.7	7.5	105.0	22.0	64.1	24.2	50.6	1.3
170	44a	( )	a	( )	( )	23.4	24.5	26.7	9.2	31.8	4.3	79.0	10.7	39.9	( )	25.4	2.6

a Not planted
b Clay pots used
c Beans grown
d Buckwheat grown

Table 13.-- Total crop yields of beans and buckwheat, grown in succession on cultivated soils.
(Cowpeas grown instead of beans 1901, 1902.)

(a = surface soil; b = subsoil.)

Pot No:	Soil No:	1895		1896		1897		1898		1899		1900		1901		1902	
		Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Cow-peas	Buck-wheat	Cow-peas	
		grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams
64	17 (a	( )	( )	26.1	19.7	41.0	26.0	23.5	13.9	19.8	9.3	44.1	21.8	108.9	1.8	183.4	
94	17 (b	( )	( )	24.2	13.7	26.6	23.9	19.7	10.6	19.2	7.4	25.0	20.0	97.2	2.5	( )	
67	18 (a	48.1	21.0	10.7	8.6	7.9	16.9	5.9	1.8	3.2	0.5	2.0	2.0	50.3	21.6	204.3	
96	18 (b	17.0	( )	7.4	10.3	7.9	9.9	8.5	5.6	6.8	2.5	3.0	5.3	74.4	3.5	166.7	
71	20 (a	47.6	31.1	27.2	32.4	32.7	37.6	25.4	18.7	27.5	13.3	65.6	23.8	95.5	2.0	64.7	
99	20 (b	23.5	9.6	15.0	8.6	15.3	14.4	16.9	5.5	16.2	4.0	17.1	9.9	62.7	4.1	49.2	
75	22 (a	[a]36.1	( )	26.3	34.3	41.1	39.2	33.9	14.7	25.7	7.1	51.0	17.1	84.0	1.2	134.3	
--	22 (b																
77	23 (a	[b]46.2	( )	49.9	50.4	43.4	46.0	38.8	15.7	28.2	6.6	63.1	25.8	87.3	0.7	( )	
105	23 (b	[b]32.3	( )	26.6	14.3	24.6	16.2	14.9	5.2	10.0	0.8	1.2	[c]33.9	3.0	0.6	235.6	
79	24 (a	[b]10.7	( )	8.9	6.8	13.8	8.2	12.1	6.5	10.0	3.7	1.3	10.7	46.4	1.4	54.2	
107	24 (b	[b]26.7	( )	20.3	25.4	12.4	15.7	11.2	3.7	7.8	1.2	1.1	[c]25.1	6.8	0.4	( )	
81	25 (a	[a]43.6	( )	31.0	46.2	31.9	33.6	32.0	7.1	20.8	3.0	13.4	17.1	60.1	0.7	126.7	
--	25 (b																
83	26 (a	64.7	( )	45.8	49.9	46.6	37.1	38.5	9.8	31.8	4.3	76.0	20.8	103.5	1.2	( )	
110	26 (b	[b]20.9	( )	20.5	10.2	11.4	11.1	10.4	1.7	8.9	1.5	0.5	5.8	3.0	0.8	( )	
88	30 (a	( )	( )	29.4	38.5	27.0	28.7	16.4	13.2	19.2	5.4	41.0	22.7	114.0	3.8	115.6	
119	30 (b	( )	( )	18.6	19.1	20.3	14.3	24.4	8.3	14.1	2.8	14.0	12.7	64.6	4.3	( )	

Table 13.-- Continued

91	32(a	[a]25.8	( )	33.5	39.5	39.7	43.4	36.5	15.3	29.0	14.5	58.3	32.2	116.2	3.0	160.3
122	32(b	[b]14.5	( )	16.7	9.1	25.4	16.4	14.5	7.3	10.7	6.6	9.3	13.5	89.7	0.4	( )
130	33a	[b]17.0	( )	15.3	15.2	12.4	15.2	13.3	5.8	7.5	3.1	7.9	9.1	70.4	0.2	( )
30	34a	15.6	( )	15.5	18.6	9.0	6.5	6.1	0.8	3.9	0.3	1.1	[c]( )	3.5	12.5	22.8
157	37a	( )	( )	( )	( )	24.2	24.4	24.7	5.5	21.9	3.5	8.4	13.2	6.0	9.8	156.3
159	38a	( )	( )	( )	( )	40.7	31.8	31.7	8.3	31.6	7.7	8.8	17.1	73.4	6.3	102.5
161	39a	( )	( )	( )	))	23.9	19.7	25.7	5.2	26.7	3.9	3.7	13.4	7.0	5.4	184.6
163	40a	( )	( )	( )	( )	41.2	38.0	28.7	14.1	40.8	8.7	20.8	24.7	104.6	18.3	117.6
165	41a	( )	( )	( )	( )	38.3	29.2	28.6	8.0	37.3	6.5	4.7	19.5	59.2	4.0	108.8
167	42a	( )	( )	( )	( )	22.5	24.7	27.7	7.3	25.9	47.0	10.3	19.2	8.9	8.1	159.9
169	43a	( )	( )	( )	( )	40.7	31.9	40.6	16.6	39.3	7.5	20.3	25.5	15.3	15.3	( )
171	44a	( )	( )	( )	( )	24.3	27.1	29.4	10.8	20.7	5.0	7.3	17.1	15.4	8.8	( )

a Buckwheat grown
b Clay pots used
c Cowpeas grown

Table 14.-- Comparison of total crop yields of oats and beans grown on the same cultivated soils.
(Cowpeas grown instead of beans in 1901, 1902.)

(a = surface soil; b = subsoil.)

Pot No:	Soil No:	1895		1896		1897		1898		1899		1900		1901		1902	
		Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Cow-peas	Oats	Cow-peas
		grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams
63-- 64:	17(a	( ):	( ):	47.7:	26.1:	19.3:	41.0:	15.7:	23.5:	19.8:	19.8:	73.5:	44.1:	18.2:	108.9:	13.9:	183.4:
93-- 94:	(b	( ):	( ):	28.1:	24.2:	7.9:	26.5:	8.2:	19.7:	7.9:	19.2:	51.8:	25.0:	10.5:	97.2:	( ):	( ):
65-- 67:	18(a	( ):	48.1:	14.5:	10.7:	25.2:	7.9:	24.0:	5.9:	29.4:	3.2:	56.3:	2.0:	52.4:	50.3:	24.4:	204.3:
95-- 96:	(b	29.5:	17.0:	7.8:	7.4:	9.9:	7.9:	10.1:	8.5:	10.0:	6.8:	24.5:	3.0:	24.3:	74.4:	18.8:	166.7:
70-- 71:	20(a	45.0:	47.6:	( ):	27.2:	23.0:	32.7:	16.0:	25.4:	8.9:	27.5:	66.3:	65.6:	59.3:	95.5:	25.7:	64.7:
98-- 99:	(b	( ):	23.5:	7.1:	15.0:	4.2:	15.3:	6.3:	16.9:	3.8:	16.2:	27.6:	17.1:	29.4:	62.7:	29.8:	49.2:
74-- 75:	22(a	[a]36.1:	[a]36.1:	41.1:	26.3:	34.8:	41.1:	30.7:	33.9:	18.4:	25.7:	67.5:	51.0:	79.9:	84.0:	55.1:	134.3:
-- --:	(b																
106-- 79:	(a	[b]10.7:	[a]10.7:	31.0:	20.3:	13.7:	12.4:	12.2:	11.2:	10.9:	7.8:	5.2:	( ):	39.6:	6.8:	( ):	( ):
78--107:	24(b	32.7:	[a]26.7:	1.9:	8.9:	2.9:	13.8:	6.1:	12.1:	2.7:	10.0:	( ):	( ):	27.1:	46.4:	39.4:	54.2:
80-- 81:	(a	27.9:	[a]43.6:	48.8:	31.0:	34.4:	31.9:	33.1:	32.0:	27.8:	20.8:	38.5:	13.4:	63.2:	60.1:	48.2:	126.7:
-- --:	25(b																
82--83 :	(a	[a]36.4:	64.7:	63.5:	45.8:	41.0:	46.6:	34.9:	38.5:	32.6:	31.8:	76.1:	76.0:	43.0:	103.5:	( ):	( ):
109--110:	26(b	35.8:	[a]20.9:	14.3:	20.5:	8.0:	11.4:	9.7:	10.4:	12.4:	8.9:	36.5:	( ):	25.6:	( ):	( ):	( ):
87-- 88:	30(a	( ):	( ):	44.0:	29.4:	24.8:	27.0:	22.3:	16.4:	21.2:	19.2:	88.1:	41.0:	40.6:	114.0:	20.0:	115.6:
118--119:	(b	( ):	( ):	16.3:	18.6:	23.6:	20.3:	22.1:	24.4:	10.4:	14.1:	19.6:	14.0:	69.8:	64.6:	( ):	( ):

Table 14.-- Continued

90-- 91:	^{32}(a	: 59.8:	[a]25.8:	35.1:	33.5:	29.1:	39.7:	35.3:	36.5:	25.1:	29.0:	85.2:	58.3:	36.5:	116.2:	37.1:	160.3:
121--122:	(b	: 38.7:	[c]14.5:	7.4:	16.7:	5.2:	25.4:	6.9:	14.5:	5.4:	10.7:	32.9:	9.3:	38.8:	89.7:	( ):	( ):
129--130:	33a	: 26.1:	[c]17.0:	14.3:	15.3:	8.8:	12.4:	10.4:	13.3:	13.2:	7.5:	50.1:	7.9:	47.9:	70.4:	64.6:	( ):
156--157:	37a	: ( ):	( ):	( ):	( ):	17.8:	24.2:	24.5:	24.7:	30.2:	21.9:	55.5:	8.4:	14.0:	6.0:	34.4:	156.3:
158--159:	38a	: ( )):	( ):	( ):	( ):	34.1:	40.7:	28.2:	31.7:	48.9:	31.6:	74.7:	8.8:	52.7:	73.4:	55.0:	102.5:
160--161:	39a	: ( ):	( ):	( ):	( ):	20.1:	23.9:	24.6:	25.7:	33.1:	26.7:	52.2:	3.7:	30.2:	7.0:	34.9:	184.6:
162--163:	40a	: ( ):	( ):	( ):	( ):	39.1:	41.2:	36.8:	28.7:	56.7:	40.8:	104.7:	20.8:	75.8:	104.6:	56.2:	117.6:
164--165:	41a	: ( ):	( ):	( ):	( ):	29.6:	38.3:	28.7:	28.6:	38.0:	37.3:	64.3:	4.7:	44.9:	59.2:	48.6:	108.8:
166--167:	42a	: ( ):	( ):	( ):	( ):	22.4:	22.5:	35.6:	27.7:	33.1:	25.9:	48.7:	10.3:	32.8:	8.9:	56.5:	159.9:
168--169:	43a	: ( ):	( ):	( ):	( ):	38.9:	40.7:	32.6:	40.6:	45.7:	39.3:	105.0:	20.3:	64.1:	( ):	50.6:	184.0:
170--171:	44a	: ( ):	( ):	( ):	( ):	23.4:	24.3:	26.7:	29.4:	31.8:	20.7:	79.0:	7.3:	39.9:	15.4:	25.4:	( ):

a Buckwheat grown
b Beans grown
c Clay pots used

Table 15.-- Nitrogen, potash, and phosphoric acid content of total crops of oats and buckwheat grown in succession on cultivated soils.

(a = surface soil; b = subsoil.)

Pot	Soil No		1895		1896		1897		1898		1899		1900		1901		1902	
			Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat
			Per cent	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cnet.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
		(N	a	a	.95	1.55	1.40	1.42	1.51	2.30	1.40	2.16	( )	1.35	.89	1.65	1.00	( )
63	17a	(K_2O	a	a	3.42	3.11	3.06	3.01	3.64	2.95	2.99	2.52	3.55	2.50	3.44	2.63	2.47	( )
		(P_2O_5	a	a	.78	1.11	2.15	1.03	1.37	1.02	1.17	.93	1.14	1.05	1.78	1.15	1.96	( )
		(N	a	a	.73	1.54	1.12	1.26	1.15	1.67	1.26	1.76	( )	1.33	.76	1.48	( )	( )
93	17b	(K_2O	a	a	3.35	3.19	2.49	2.68	2.98	3.45	2.91	2.42	3.40	2.63	3.56	2.55	( )	( )
		(P_2O_5	a	a	.52	.94	1.51	.95	1.27	.72	.88	.52	.68	1.40	1.42	1.18	( )	( )
		(N	.92	a	1.21	2.13	1.30	2.33	1.37	( )	1.62	( )	1.85	2.80	1.06	( )	1.15	( )
65	18a	(K_2O	3.18	a	1.92	3.12	2.56	3.31	3.06	1.79	2.16	( )	2.74	( )	( )	( )	2.33	( )
		(P_2O_5	.42	a	.66	.40	.50	.44	.77	.44	.38	( )	.45	( )	( )	( )	.55	( )
		(N	.96	a	1.02	1.65	1.14	1.72	.97	1.77	( )	( )	1.14	1.40	.76	1.74	1.18	7.37
95	18b	(K_2O	3.12	a	2.36	2.73	1.44	2.82	3.00	2.75	2.47	3.30	2.74	3.13	2.79	2.35	1.72	1.86
		(P_2O_5	.39	a	.58	.40	.60	.25	.56	.31	.50	.28	.49	.63	.72	1.14	1.23	1.25
		(N	1.36	a	1.22	2.31	1.23	2.18	1.49	2.38	1.55	( )	( )	2.35	1.35	( )	1.30	3.04
69	19a	(K_2O	3.30	a	3.07	1.30	2.77	2.64	2.90	2.43	2.65	2.61	2.21	1.72	1.44	( )	1.26	1.68
		(P_2O_5	.43	a	.36	.33	.54	.24	.37	.36	.40	.28	.46	.69	.44	( )	.50	.80
		(N	2.21	a	1.01	2.27	1.40	2.16	1.11	( )	.84	( )	1.19	2.70	.96	1.48	1.25	2.90
101	19b	(K_2O	2.67	a	2.46	3.13	2.21	3.50	3.11	3.01	2.69	( )	3.03	( )	1.37	4.90	.58	1.32
		(P_2O_5	.53	a	.42	.29	.43	.17	.34	.36	.31	( )	.49	( )	.45	1.54	.34	.76

Table 15.-- Continued

	(N	1.39	a	( )	1.34	1.41	1.69	1.83	1.93	2.79	2.23	1.75	2.11	.78	2.16	1.07	( )
70:	20a(K_2O	2.29	a	( )	2.60	2.76	2.46	3.21	2.52	2.64	2.10	3.30	1.72	2.24	.33	1.71	( )
	(P_2O_5	.66	a	( )	.50	.68	.58	.78	.44	.51	.35	.63	1.17	.43	.22	.79	( )
	(N	.68	a	1.13	( )	1.11	1.26	1.39	1.96	( )	( )	9.68	1.54	.90	1.90	1.41	2.32
98:	20b(K_2O	2.98	a	3.05	( )	3.40	2.33	3.33	2.67	3.03	2.54	3.41	2.29	3.24	.30	2.28	2.54
	(P_2O_5	.27	a	.54	( )	.72	.43	.68	.33	.33	.35	.39	.61	.39	.17	.37	.28
	(N	1.38	a	1.20	1.47	1.40	1.85	1.47	2.39	1.82	( )	2.05	3.00	1.45	( )	1.38	3.40
73:	21a(K_2O	2.28	a	1.62	2.20	1.70	2.47	1.60	2.40	1.80	1.85	2.00	1.58	.77	( )	1.12	1.01
	(P_2O_5	.36	a	.47	.39	.55	.37	.40	.40	.42	.23	.26	.99	.83	( )	.72	1.59
	(N	2.05	a	1.22	1.82	1.32	1.68	1.77	2.33	( )	( )	1.70	2.17	.76	( )	( )	( )
102:	21b(K_2O	2.26	a	2.60	2.40	2.84	2.45	3.27	2.45	2.88	2.92	2.94	2.16	1.60	( )	( )	( )
	(P_2O_5	.23	a	.38	.27	.37	.13	.17	.21	.22	.70	.51	.57	1.02	( )	( )	( )
	(N	1.39	a	1.31	1.74	1.45	2.24	1.55	2.79	2.15	2.71	2.64	2.62	1.65	( )	1.53	2.97
74:	22a(K_2O	2.24	a	2.57	2.21	1.78	2.12	2.12	2.42	2.44	2.41	1.85	1.54	1.08	( )	1.18	1.08
	(P_2O_5	.83	a	.57	.69	.52	.61	.70	.81	.60	.63	1.00	1.15	.52	( )	.46	.8[illegible]
	(N	1.37	a	1.36	1.61	1.22	1.61	1.51	2.32	( )	( )	1.67	1.68	.93	1.74	( )	( )
103:	22b(K_2O	2.06	a	2.98	2.64	2.98	2.57	2.92	2.67	2.08	2.18	2.60	2.18	2.80	1.77	( )	( )
	(P_2O_5	.41	a	.70	.43	.57	.43	.74	.44	.51	.38	.43	.82	.50	.70	( )	( )
	(N	2.43	a	1.02	1.64	1.24	1.92	1.59	2.65	1.72	2.42	2.14	2.37	1.00	( )	( )	( )
76:	23a(K_2O	3.05	a	3.90	3.47	4.60	3.56	4.94	4.71	4.13	3.29	4.97	4.47	3.52	( )	( )	( )
	(P_2O_5	.61	a	1.17	.69	.78	.74	.62	1.09	.54	.71	.97	1.92	.71	( )	( )	( )
	(N	2.56	a	1.17	1.55	1.14	1.85	2.11	2.30	1.76	( )	1.95	1.30	1.15	( )	1.22	( )
104:	23b(K_2O	3.03	a	3.47	2.93	3.11	2.67	3.30	2.57	3.71	2.70	3.70	2.58	3.36	( )	2.27	( )
	(P_2O_5	.53	a	.42	.35	.53	.30	.10	.36	.28	.25	.45	.41	.32	( )	1.13	( )

Table 15.-- Continued

	(N	2.31	a	1.22	1.76	1.40	2.04	1.72	2.83	( )	( )	2.06	3.26	1.58	( )	( )	( )	
106	24a (K_2O	2.14	a	1.28	1.47	.77	1.33	.76	2.18	1.36	2.52	2.39	( )	1.96	( )	( )	( )	
	(P_2O_5	.75	a	.75	.44	.46	.39	.35	.40	.44	.38	.29	( )	.23	( )	( )	( )	
	(N	1.73	a	.97	1.42	.80	1.28	1.48	1.79	.94	( )	1.77	1.50	1.13	( )	1.30	( )	
78	24b (K_2O	1.21	a	1.76	2.89	2.60	3.15	2.67	2.54	2.19	2.65	( )	2.04	2.13	( )	2.40	( )	
	(P_2O_5	.50	a	.75	.56	.73	.51	.76	.50	1.50	.16	( )	.59	.41	( )	.50	( )	
	(N	2.05	a	1.33	1.49	1.51	1.97	1.52	2.41	1.71	( )	2.23	2.60	1.51	1.96	1.57	3.10	
80	25a (K_2O	3.59	a	2.94	3.08	2.65	2.25	1.88	2.36	1.92	2.00	2.24	2.07	.84	1.05	.93	1.08	
	(P_2O_5	.49	a	.54	.51	.58	.50	.48	.47	.52	.52	.52	.93	.97	.80	.43	.75	
	(N	( )	a	1.06	1.65	1.13	1.53	1.16	1.97	( )	( )	1.26	1.40	.81	1.99	( )	( )	
108	25b (K_2O	( )	a	2.78	3.11	3.11	3.92	3.12	3.28	3.10	2.95	3.04	3.00	2.53	1.89	( )	( )	
	(P_2O_5	( )	a	.52	.40	.64	.57	.53	.30	.73	.17	.59	.63	1.20	.75	( )	( )	
	(N	.95	a	1.27	1.80	1.44	2.03	1.13	2.87	( )	( )	1.91	2.10	.90	1.93	( )	( )	
82	26a (K_2O	3.37	a	3.84	3.72	3.93	3.18	3.70	3.72	3.10	3.02	4.36	4.12	3.79	.48	( )	( )	
	(P_2O_5	.94	a	.97	.70	1.08	.72	.81	.91	.88	.84	1.34	2.38	1.52	.30	( )	( )	
	(N	.94	a	.95	1.44	1.25	1.91	1.41	2.14	( )	( )	1.40	2.06	.80	( )	( )	( )	
109	26b (K_2O	2.65	a	2.80	2.53	2.30	2.64	2.91	2.51	2.93	3.11	3.59	2.35	2.91	( )	( )	( )	
	(P_2O_5	.28	a	.54	.34	.58	.28	.50	.27	.39	.29	.51	.72	1.76	( )	( )	( )	
	(N	( )	a	.97	1.53	1.44	1.53	1.15	1.88	1.24	1.85	1.12	1.95	.83	1.68	.95	( )	
84	27a (K_2O	( )	a	3.30	3.07	3.54	1.03	2.28	3.30	3.21	2.74	3.52	3.13	4.10	( )	2.50	2.35	
	(P_2O_5	( )	a	.84	.89	1.03	.39	.96	.74	1.45	.62	.79	1.43	1.17	( )	.83	.94	
	(N	( )	a	.92	1.33	.97	1.38	1.15	1.78	( )	( )	1.11	1.92	.80	1.74	( )	( )	
111	27b (K_2O	( )	a	3.19	2.16	3.03	1.96	3.62	2.26	3.16	2.18	2.97	3.50	5.01	( )	( )	( )	
	(P_2O_5	( )	a	.55	.33	.48	.26	.45	.25	.32	.71	.34	.71	.58	( )	( )	( )	

Table 15.-- Continued

	(N	( )	a	1.62	1.53	1.82	2.90	2.24	2.55	1.98	2.06	( )	2.54	.98	( )	1.26	3.20
85	28a (K_2O	( )	a	4.28	3.31	3.15	2.90	2.56	3.27	2.93	3.14	2.51	1.84	1.73	( )	1.40	1.06
	(P_2O_5	( )	a	1.40	.90	.57	.77	.60	.72	.63	1.13	1.28	1.15	.84	( )	.78	1.08
	(N	1.00	a	1.11	1.47	1.56	2.04	1.65	1.73	1.64	2.01	1.31	1.57	.90	( )	( )	( )
112	28b (K_2O	3.19	a	2.92	2.64	3.31	2.04	2.66	3.06	2.84	2.66	2.62	3.06	2.82	( )	( )	( )
	(P_2O_5	.44	a	1.41	.99	1.27	.97	.41	.62	.74	.52	1.49	1.79	1.12	( )	( )	( )
	(N	( )	a	1.39	1.39	1.22	1.59	1.45	2.55	1.48	2.58	1.61	2.48	.80	2.04	( )	( )
86	29a (K_2O	( )	a	3.82	3.60	3.05	4.55	3.77	3.24	3.04	2.46	2.35	1.83	2.48	( )	( )	( )
	(P_2O_5	( )	a	1.04	1.08	1.83	1.41	2.02	1.03	1.71	.67	1.38	1.75	1.02	( )	( )	( )
	(N	( )	a	.94	1.61	1.15	1.56	1.21	2.53	1.18	( )	1.12	1.60	.90	( )	( )	( )
113	29b (K_2O	( )	a	2.92	1.88	2.66	2.91	5.40	2.20	2.47	1.87	2.32	2.12	2.86	( )	( )	( )
	(P_2O_5	( )	a	.46	.95	.90	.37	.91	.47	.46	.31	1.09	.74	.99	( )	( )	( )
	(N	( )	a	1.48	1.59	1.22	1.99	1.19	2.38	1.50	2.23	1.82	2.07	.83	1.60	1.27	2.75
87	30a (K_2O	( )	a	2.87	2.46	2.72	2.48	2.52	2.62	2.37	2.19	2.33	2.08	2.09	.55	1.66	.97
	(P_2O_5	( )	a	.31	.44	.56	.46	.38	.49	.43	.52	.44	1.03	.55	.18	.70	.43
	(N	( )	a	1.69	2.01	1.45	1.88	1.65	2.21	( )	( )	1.85	2.10	1.11	1.57	( )	( )
118	30b (K_2O	( )	a	3.39	1.94	3.43	1.79	3.45	2.02	3.80	1.63	2.95	2.35	2.08	2.51	( )	( )
	(P_2O_5	( )	a	.40	.38	.29	.24	.30	.10	.22	.09	.30	.68	.63	1.20	( )	( )
	(N	1.90	a	1.34	1.52	1.21	1.91	1.54	2.43	1.41	( )	1.50	1.90	1.00	( )	1.44	3.35
89	31a (K_2O	2.46	a	2.57	2.08	2.97	3.13	1.95	2.35	2.03	( )	2.52	2.13	.73	( )	.78	1.21
	(P_2O_5	.56	a	.33	.31	.34	.34	.43	.40	.40	( )	.35	.65	1.55	( )	.70	1.46
	(N	1.87	a	1.20	1.53	1.52	1.44	1.35	1.89	( )	( )	1.17	2.16	1.15	2.30	( )	( )
120	31b (K_2O	2.26	a	1.74	3.23	2.80	2.58	2.42	3.06	1.53	2.78	3.11	2.77	1.63	1.34	( )	( )
	(P_2O_5	.44	a	.75	.50	.90	.45	.57	.37	.46	.21	.75	.66	.38	.91	( )	( )

Table 15.-- Continued

	(N	1.13	a	1.15	1.23	1.97	1.69	1.22	2.40	1.63	1.63	1.50	1.68	1.05	1.82	1.15	3.00
90	32a (K_2O	2.85	a	2.81	2.74	3.15	2.57	2.96	2.40	2.74	2.74	1.89	2.30	2.77	2.18	1.70	1.56
	(P_2O_5	1.02	a	1.46	.94	1.56	1.17	1.65	.96	1.75	1.75	1.28	1.10	2.26	1.44	.85	.95
	(N	.63	a	1.01	1.27	1.22	1.53	.88	1.48	1.03	1.45	1.21	1.65	.92	( )	( )	( )
121	32b (K_2O	2.87	a	1.73	3.12	( )	1.88	2.55	3.51	2.53	2.92	2.61	2.98	2.95	( )	( )	( )
	(P_2O_5	1.20	a	1.86	1.07	2.68	1.38	1.62	1.03	2.64	1.02	2.19	2.24	1.03	( )	( )	( )
	(N	.76	a	.86	1.54	1.61	1.72	1.19	2.45	( )	( )	1.26	1.85	.81	( )	1.16	2.96
129	33a (K_2O	2.94	a	2.60	3.13	2.92	3.56	3.48	3.38	3.08	2.56	3.42	3.44	2.82	( )	1.77	1.84
	(P_2O_5	1.18	a	1.47	1.09	1.89	1.30	1.92	.91	1.14	.61	2.15	1.01	1.08	( )	.77	1.03
	(N	1.52	a	1.14	1.97	1.44	1.97	1.33	( )	1.41	( )	2.06	( )	1.62	1.93	1.68	3.00
29	34a (K_2O	2.77	a	2.69	2.96	2.42	2.32	2.12	1.91	1.81	1.42	2.58	( )	1.12	1.16	1.28	1.41
	(P_2O_5	.49	a	.53	.35	.77	.34	.67	.18	.51	.30	.52	( )	.44	.78	.44	.52
	(N	1.82	a	1.30	1.51	1.57	2.34	1.90	2.80	1.94	2.81	1.88	1.74	1.08	2.24	1.16	( )
131	35a (K_2O	2.39	a	2.16	1.95	1.53	1.37	1.18	1.12	1.48	1.52	1.27	2.65	1.06	1.26	1.38	( )
	(P_2O_5	.61	a	1.23	.85	1.36	.81	.62	.76	.55	.62	.86	1.15	.54	1.10	.61	( )
	(N	( )	a	( )	( )	1.18	( )	1.58	2.85	( )	( )	1.60	1.87	.96	1.62	( )	( )
151	36a (K_2O	( )	a	( )	( )	3.85	( )	3.98	3.34	3.81	3.17	3.42	2.90	3.02	1.94	( )	( )
	(P_2O_5	( )	a	( )	( )	.77	( )	.65	.61	.48	.40	.49	1.38	.56	.49	( )	( )
	(N	( )	a	( )	( )	2.14	2.18	1.70	2.63	1.89	2.35	1.90	2.66	1.58	1.96	1.66	2.54
156	37a (K_2O	( )	a	( )	( )	4.20	2.26	2.96	2.71	2.31	2.04	2.63	2.83	2.10	( )	1.37	2.67
	(P_2O_5	( )	a	( )	( )	.69	.49	.56	.51	.37	.18	.34	.99	.58	( )	.43	.34

Table 15.-- Continued

	(N	( )	a	( )	( )	1.70	1.84	1.48	3.03	1.78	2.94	1.93	3.14	1.52	2.77	1.64	( )
158:	38a(K2O	( )	a	( )	( )	2.76	2.11	1.93	2.17	1.72	2.02	1.79	6.56	.84	1.36	1.05	( )
	(P2O5	( )	a	( )	( )	.94	1.17	.88	1.31	.53	.97	.98	2.81	.49	1.26	.56	( )
	(N	( )	a	( )	( )	1.56	2.26	1.31	2.79	1.65	1.65	1.88	2.97	1.50	2.00	1.67	2.18
160:	39a(K2O	( )	a	( )	( )	4.00	2.74	2.96	2.72	1.77	1.77	2.38	2.43	1.70	( )	1.54	1.81
	(P2O5	( )	a	( )	( )	.74	.47	.51	.47	.31	.31	.19	.91	.58	( )	.52	.19
	(N	( )	a	( )	( )	1.55	1.68	1.15	3.20	1.24	2.38	1.69	2.21	1.24	2.10	1.05	2.86
162:	40a(K2O	( )	a	( )	( )	6.30	3.92	4.53	4.97	4.17	2.92	4.02	3.65	2.70	2.63	2.56	3.94
	(P2O5	( )	a	( )	( )	1.28	1.13	1.05	1.03	.64	.77	.88	2.00	.52	1.30	.77	2.13
	(N	( )	a	( )	( )	1.36	2.00	1.21	3.46	1.24	2.64	1.82	2.83	1.42	2.88	1.73	3.20
164:	41a(K2O	( )	a	( )	( )	3.18	2.32	1.13	1.95	1.35	1.80	1.72	( )	.88	( )	1.20	1.54
	(P2O5	( )	a	( )	( )	1.44	1.47	( )	1.02	.48	.50	.86	( )	.50	( )	.60	1.97
	(N	( )	a	( )	( )	1.58	2.01	2.96	2.73	1.36	2.24	2.13	( )	1.40	1.80	1.48	2.14
166:	42a(K2O	( )	a	( )	( )	4.92	3.38	4.48	3.54	3.50	2.63	4.31	3.18	3.36	2.94	2.77	4.09
	(P2O5	( )	a	( )	( )	.79	.45	.52	.42	.38	.24	.37	1.06	.48	.44	.46	.30
	(N	( )	a	( )	( )	1.39	1.50	1.19	2.49	1.04	( )	( )	2.58	.90	1.65	1.00	2.92
168:	43a(K2O	( )	a	( )	( )	5.37	( )	3.78	4.15	4.06	3.06	4.22	2.93	3.53	2.41	2.80	3.33
	(P2O5	( )	a	( )	( )	1.31	( )	1.17	.99	.74	1.00	1.04	1.75	1.31	1.10	.89	1.04
	(N	( )	a	( )	( )	1.38	1.51	1.19	2.29	1.35	2.29	1.66	2.74	1.12	1.74	1.44	2.10
170:	44a(K2O	( )	a	( )	( )	4.37	2.59	2.68	2.28	2.25	2.64	1.42	2.98	2.25	( )	1.73	1.73
	(P2O5	( )	a	( )	( )	.64	.54	.63	.40	.38	.37	.32	1.11	.27	( )	.66	.25

a Not planted

Table 16.-- Nitrogen, potash, and phosphoric acid content of total crops of beans and buckwheat grown in succession on virgin soils. (Cowpeas grown instead of beans in 1901, 1902.)

(a = surface soil; b = subsoil.)

Pot	Soil No	1895		1896		1897		1898		1899		1900		1901		1902	
		Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Cow-peas	Buck-wheat	Cow-peas	Buck-wheat
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
64	17a (N	( )	( )	2.11	1.51	2.61	1.35	2.42	2.02	( )	( )	2.36	1.45	3.30	( )	1.81	
	17a (K_2O	( )	( )	2.63	3.50	2.29	3.14	3.14	3.85	3.51	2.95	2.03	2.54	2.69	( )	.98	
	17a (P_2O_5	( )	( )	.66	1.00	.71	1.04	.95	.93	.80	.94	1.37	1.66	.60	( )	.24	
94	17b (N	( )	( )	2.10	1.30	2.35	1.25	2.64	1.67	( )	( )	2.80	1.48	2.60	( )	( )	
	17b (K_2O	( )	( )	2.31	3.12	1.91	( )	2.61	2.87	2.83	2.13	3.29	2.59	1.78	( )	( )	
	17b (P_2O_5	( )	( )	.50	.90	.66	( )	.86	1.03	.77	.70	.76	1.11	.45	( )	( )	
67	18a (N	1.43	1.72	2.72	2.20	3.52	2.40	4.62	2.74	( )	( )	5.60	( )	3.45	2.07	2.20	
	18a (K_2O	2.75	2.52	2.94	3.20	3.82	3.58	2.98	2.60	3.52	( )	2.05	( )	2.74	( )	.84	
	18a (P_2O_5	.68	.62	.58	.38	.46	.66	.53	.40	1.00	( )	.89	( )	.65	.98	.30	
96	18b (N	2.35	( )	2.55	1.61	2.64	1.85	4.24	2.02	( )	( )	( )	2.08	2.57	( )	2.36	
	18b (K_2O	2.81	( )	3.40	2.99	4.00	2.56	3.63	2.96	3.22	2.98	3.10	3.11	2.74	( )	.82	
	18b (P_2O_5	.55	( )	.63	.40	.56	.37	.74	.41	.65	.31	.41	.61	.52	( )	.51	
71	20a (N	2.03	1.55	2.32	1.37	2.39	1.68	2.56	1.84	( )	( )	2.83	1.70	2.32	( )	2.02	
	20a (K_2O	1.70	2.42	1.67	2.48	1.48	2.50	1.78	2.61	1.82	2.03	1.16	1.97	1.15	( )	.70	
	20a (P_2O_5	.67	.49	.71	.46	.48	.50	.77	.42	.66	.43	.67	1.14	.50	( )	.29	
99	20b (N	2.01	1.32	( )	1.39	2.65	1.42	2.45	2.02	( )	( )	2.64	1.44	2.06	( )	1.98	
	20b (K_2O	2.45	1.82	( )	2.13	2.29	( )	2.82	1.22	3.55	2.70	3.12	1.53	1.88	( )	1.26	
	20b (P_2O_5	.52	.44	( )	.46	.35	( )	.57	.62	.50	.42	.53	.41	.11	( )	.36	

Table 16.-- Continued

	(N	[a]1.39	( )	2.27	1.48	2.54	2.03	2.81	2.64	( )	( )	3.65	2.56	2.70	( )	1.80	
75	22a (K$_2$O	2.24	( )	1.88	2.57	1.80	2.41	1.81	2.39	2.22	2.14	1.25	1.86	1.12	( )	.60	
	(P$_2$O$_5$	.83	( )	.67	.62	.69	.64	.94	.71	.93	.66	.72	1.19	.52	( )	.34	
	(N																
--	22b (K$_2$O																
	(P$_2$O$_5$																
	(N	[b]2.43	( )	2.45	1.82	2.61	1.73	3.03	2.66	1.72	( )	3.15	3.20	2.80	( )	( )	
77	23a (K$_2$O	3.05	( )	3.32	4.04	2.71	3.57	3.37	4.92	4.18	3.96	3.66	3.56	4.22	( )	( )	
	(P$_2$O$_5$	.61	( )	.94	.81	.67	.88	.64	1.05	.94	1.09	.74	1.33	.48	( )	( )	
	(N	[b]2.56	( )	2.46	1.71	2.37	1.93	3.01	2.58	( )	( )	2.13	[c]2.18	2.95	( )	2.47	
105	23b (K$_2$O	3.03	( )	2.60	2.83	2.75	2.69	4.08	3.13	4.30	3.02	( )	[c]4.48	( )	( )	1.73	
	(P$_2$O$_5$	.53	( )	.49	.35	.51	.34	.64	.50	.66	.36	( )	[c] .62	( )	( )	.22	
	(N	[b]2.31	( )	2.05	1.34	2.45	1.46	2.87	1.95	( )	( )	( )	2.45	2.63	( )	2.06	
79	24a (K$_2$O	2.14	( )	1.61	2.51	1.41	2.47	2.19	2.32	2.83	1.96	( )	2.01	1.70	( )	1.38	
	(P$_2$O$_5$	.75	( )	.57	.54	.38	1.08	1.02	.47	.84	.15	( )	.75	.28	( )	.33	
	(N	[b]1.94	( )	2.50	1.76	2.58	1.53	3.75	2.81	( )	( )	3.98	[c]3.95	3.66	( )	( )	
107	24b (K$_2$O	1.09	( )	1.13	1.47	1.19	1.60	1.72	2.25	( )	2.43	( )	[c]1.80	3.70	( )	( )	
	(P$_2$O$_5$	.75	( )	.75	.43	.60	.34	.62	.45	( )	.32	( )	[c]1.12	.18	( )	( )	
	(N	[b]2.44	( )	2.40	1.61	2.49	1.97	3.01	2.45	( )	( )	4.63	2.06	2.60	( )	2.00	
81	25a (K$_2$O	2.49	( )	2.50	3.10	2.30	2.45	2.30	2.36	2.62	2.46	2.65	2.37	1.08	( )	.61	
	(P$_2$O$_5$	.58	( )	.64	.45	.80	.39	.67	.44	.70	.20	.50	.67	.54	( )	.21	
	(N																
--	25b (K$_2$O																
	(P$_2$O$_5$																

Table 16.-- Continued

83:	26a	(N	2.07	( )	2.23	1.69	2.34	2.00	2.58	2.78	( )	( )	3.12	2.10	3.10	( )	( )
		(K_2O	3.43	( )	3.56	3.53	2.47	3.60	3.03	3.61	3.54	3.20	2.27	3.33	2.45	( )	( )
		(P_2O_5	.72	( )	.74	.72	.65	.84	.81	.85	1.00	1.04	1.02	1.86	.92	( )	( )
110:	26b	(N	[b]2.33	( )	2.63	1.24	2.65	2.17	4.15	2.36	( )	( )	5.23	5.00	3.40	( )	( )
		(K_2O	2.38	( )	2.91	2.81	2.83	2.59	3.86	2.85	3.75	3.09	( )	4.11	( )	( )	( )
		(P_2O_5	.54	( )	.43	.34	.53	.32	.65	.30	.70	.34	( )	.56	( )	( )	( )
88:	30a	(N	( )	( )	2.39	1.33	2.17	1.77	2.63	2.61	( )	( )	3.12	2.30	2.87	( )	1.90
		(K_2O	( )	( )	2.30	2.46	1.78	2.65	1.96	2.36	1.87	2.04	3.19	2.74	.91	( )	.69
		(P_2O_5	( )	( )	.46	.42	.50	.33	.71	.51	.72	.60	1.07	1.06	.33	( )	.20
119:	30b	(N	( )	( )	2.71	1.41	2.27	1.73	2.39	1.95	( )	( )	3.47	1.68	2.80	( )	( )
		(K_2O	( )	( )	2.64	2.05	2.40	2.10	2.41	2.33	2.79	1.52	3.38	2.24	1.82	( )	( )
		(P_2O_5	( )	( )	.33	.34	.40	.33	.44	.30	.43	.27	.27	.56	.55	( )	( )
91:	32a	(N	[a]1.18	( )	2.58	1.45	2.64	1.69	2.47	2.42	( )	( )	2.62	1.56	2.96	( )	1.90
		(K_2O	3.14	( )	2.42	2.83	1.45	2.46	1.83	2.81	2.07	2.12	1.38	2.23	.85	( )	.47
		(P_2O_5	1.53	( )	.95	.92	1.86	1.21	.94	1.13	1.10	1.00	1.22	1.83	.83	( )	.43
122:	32b	(N	[b]1.74	( )	2.59	1.43	2.70	1.35	2.67	1.33	( )	( )	3.27	2.04	3.17	( )	( )
		(K_2O	2.40	( )	2.41	3.00	2.10	2.78	3.21	3.57	3.21	3.01	3.69	2.52	1.79	( )	( )
		(P_2O_5	.79	( )	.93	1.00	.76	.86	.90	.82	1.00	.91	1.27	1.65	.55	( )	( )
130:	33a	(N	[b]2.35	( )	2.50	1.64	2.99	1.63	3.27	2.40	( )	( )	3.89	1.93	3.15	( )	( )
		(K_2O	2.81	( )	2.93	3.19	3.00	3.47	3.61	3.63	4.00	3.19	3.88	2.72	1.65	( )	( )
		(P_2O_5	.55	( )	.91	.85	.81	1.42	.95	.85	.73	.84	.73	1.00	.55	( )	( )
30:	34a	(N	1.94	( )	2.65	1.79	2.91	2.39	4.38	( )	( )	( )	( )	[c]4.00	3.50	1.93	2.94
		(K_2O	3.44	( )	2.81	3.09	2.51	3.32	3.30	2.43	2.70	2.53	( )	[c]( )	( )	1.60	2.79
		(P_2O_5	.85	( )	.56	.36	.58	.45	.70	.38	.67	.44	( )	[c]( )	( )	.76	.35

Table 16.-- Continued

	(N	( )	( )	( )	( )	2.37	2.24	3.01	2.88	( )	( )	4.94	2.13	3.50	2.13	3.14	
157:	37a(K2O	( )	( )	)	( )	2.83	2.68	2.03	2.52	2.01	2.28	2.35	.98	1.68	2.09	1.06	
	(P2O5	( )	( )	( )	( )	.62	.58	.64	.53	.32	.14	( )	.90	.39	.52	.34	
	(N	( )	( )	( )	( )	1.87	2.12	2.99	2.26	( )	( )	4.74	2.44	2.90	3.40	1.90	
159:	38a(K2O	( )	( )	( )	( )	1.73	2.46	1.92	2.28	1.65	2.17	1.94	2.56	1.10	1.92	.53	
	(P2O5	( )	( )	( )	( )	.82	1.13	1.10	.73	.97	.80	( )	1.72	.53	1.96	.42	
	(N	( )	( )	( )	( )	2.21	2.26	2.70	2.93	( )	( )	5.58	2.27	4.00	2.46	1.80	
161:	39a(K2O	( )	( )	( )	( )	4.43	2.94	2.61	3.00	2.73	2.20	2.01	3.07	2.05	2.48	1.09	
	(P2O5	( )	( )	( )	( )	.72	.49	.74	.58	.57	.26	.26	.79	.44	.48	.22	
	(N	( )	( )	( )	( )	2.29	1.85	2.54	2.79	1.24	( )	3.91	2.07	3.32	2.44	2.10	
163:	40a(K2O	( )	( )	( )	( )	3.07	4.23	3.43	4.51	3.28	3.18	3.63	3.44	2.49	( )	1.36	
	(P2O5	( )	( )	( )	( )	.65	1.12	.98	.98	.83	.85	.41	2.02	.50	( )	.34	
	(N	( )	( )	( )	( )	1.71	2.31	3.04	3.17	( )	( )	4.89	2.83	2.78	( )	1.70	
165:	41a(K2O	( )	( )	( )	( )	1.91	2.51	1.74	( )	1.64	2.32	1.56	2.87	1.42	( )	.54	
	(P2O5	( )	( )	( )	( )	.89	1.45	1.01	1.11	.91	1.00	( )	2.28	.59	( )	.40	
	(N	( )	( )	( )	( )	2.55	1.92	1.19	2.49	( )	( )	4.86	1.96	3.34	2.27	1.88	
167:	42a(K2O	( )	( )	( )	( )	3.48	3.59	3.95	3.75	3.88	3.06	3.75	1.38	3.97	2.38	2.80	
	(P2O5	( )	( )	( )	( )	.71	.48	.75	.44	.70	.25	( )	1.17	.39	.46	.20	
	(N	( )	( )	( )	( )	1.52	1.66	2.50	2.46	( )	( )	4.45	2.30	3.40	2.27	( )	
169:	43a(K2O	( )	( )	( )	( )	2.92	3.71	2.99	4.32	2.88	3.26	4.10	3.15	2.17	2.12	( )	
	(P2O5	( )	( )	( )	( )	.85	1.70	.88	1.04	1.26	1.04	.55	1.90	.79	.77	( )	

Table 16.-- Continued

	(N	( )	( )	( )	( )	2.18	1.64	2.70	2.43	( )	( )	4.91	2.41	3.50	2.38	( )	
171	44a(K_2O	( )	( )	( )	( )	2.28	2.66	2.30	2.59	2.56	2.38	2.41	2.66	1.73	1.91	( )	
	(P_2O_5	( )	( )	( )	( )	.64	.45	.76	.43	.62	.34	( )	1.03	.54	.44	( )	

a Buckwheat grown
b Clay pots used
c Cowpeas grown

Table 17.-- Comparison of nitrogen, potash, and phosphoric acid content of total crops of oats and beans grown on the same cultivated soils. (Cowpeas grown instead of beans in 1901, 1902.)

(a = surface soil; b = subsoil.)

Pot No	Soil, No		1895		1896		1897		1898		1899		1900		1901		1902	
			Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Cow-peas	Oats	Cow-peas
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
63- 64	17a	(N	( )	( )	.95	2.11	1.40	2.61	1.51	2.42	1.40	( )	1.14	2.36	.89	3.30	1.00	1.81
		(K_2O	( )	( )	3.42	2.63	3.06	2.29	3.64	3.14	2.99	3.51	3.55	2.03	3.44	2.69	2.47	.98
		(P_2O_5	( )	( )	.78	.66	2.15	.71	1.37	.95	1.17	.80	1.14	1.37	1.78	.60	1.96	.24
93- 94	17b	(N	( )	( )	.73	2.10	1.12	2.35	1.15	2.64	1.26	( )	.80	2.80	.76	2.60	( )	( )
		(K_2O	( )	( )	3.35	2.31	2.49	1.91	2.98	2.61	2.91	2.83	3.40	3.29	3.56	1.78	( )	( )
		(P_2O_5	( )	( )	.52	.50	1.51	.66	1.27	.86	.88	.77	.68	.76	1.42	.45	( )	( )
65 - 67	18a	(N	.92	1.43	1.21	2.72	1.30	3.52	1.37	4.62	1.62	( )	1.85	5.60	1.06	3.45	1.15	2.20
		(K_2O	3.18	2.75	1.92	2.94	2.56	3.82	3.06	2.98	2.16	3.52	2.74	2.05	( )	2.74	2.33	.84
		(P_2O_5	.42	.68	.66	.58	.50	.46	.77	.53	.38	1.00	.45	.89	( )	.65	.55	.30
95- 96	18b	(N	.96	2.35	1.02	2.55	1.14	2.64	.97	4.24	( )	( )	1.14	( )	.76	2.57	1.18	2.36
		(K_2O	3.12	2.81	2.36	3.40	1.44	4.00	3.00	3.63	2.47	3.22	2.74	3.10	2.79	3.74	1.72	.82
		(P_2O_5	.39	.55	.58	.63	.60	.56	.56	.74	.50	.65	.49	.41	.72	.52	1.23	.51
70- 71	20a	(N	1.38	2.03	( )	2.32	1.41	2.39	1.83	2.56	2.79	( )	1.75	2.83	.78	2.32	1.07	2.02
		(K_2O	2.29	1.70	( )	1.67	2.76	1.48	3.21	1.78	2.46	1.82	3.30	1.16	2.24	1.15	1.71	.70
		(P_2O_5	.66	.67	( )	.71	.68	.48	.78	.77	.51	.66	.63	.67	.43	.50	.79	.29
98- 99	20b	(N	.68	2.01	1.13	( )	1.11	2.65	1.39	2.45	( )	( )	1.68	2.64	.90	2.06	1.41	1.08
		(K_2O	2.98	2.45	3.05	( )	3.40	2.29	3.33	2.82	3.03	3.55	3.41	3.12	3.24	1.88	2.28	1.26
		(P_2O_5	.27	.52	.54	( )	.72	.35	.68	.57	.33	.50	.39	.53	.39	.11	.37	.36

Table 17.-- Continued

74- 75	22a	(N	1.39	1.39	1.31	2.27	1.45	2.54	1.55	2.81	2.15	( )	2.64	3.65	1.65	2.70	1.53	1.80
		(K_2O	2.24	2.24	2.57	1.88	1.78	1.80	2.12	1.81	2.44	2.22	1.85	1.26	1.08	1.12	1.18	.60
		(P_2O_5	.83	.83	.57	.67	.52	.69	.70	.94	.60	.93	1.00	.72	.52	.52	.46	.34
-- --	22b	(N																
		(K_2O																
		(P_2O_5																
106- 79	24a	(N	2.31	( )	1.22	2.05	1.40	2.45	1.72	2.87	( )	( )	2.06	3.98	1.58	3.66	( )	( )
		(K_2O	2.14	( )	1.28	1.61	.77	1.41	.76	2.19	1.36	2.83	2.39	( )	1.96	3.70	( )	( )
		(P_2O_5	.75	( )	.75	.57	.46	.38	.35	1.02	.44	.84	.29	( )	.23	.18	( )	( )
78-107	24b	(N	1.73	[b]1.94	.97	2.50	.80	2.58	1.48	3.75	.94	( )	1.77	( )	1.13	2.63	1.30	2.06
		(K_2O	1.21	1.09	1.76	1.13	2.60	1.19	2.67	1.72	2.19	( )	( )	( )	2.13	1.70	2.40	1.38
		(P_2O_5	.50	.75	.75	.75	.73	.60	.76	.62	1.50	( )	( )	( )	.41	.28	.50	.33
80- 81	25a	(N	2.05	[b]2.44	1.33	2.40	1.51	2.49	1.52	3.01	1.71	( )	2.23	4.63	1.51	2.60	1.57	2.00
		(K_2O	3.59	2.49	2.94	2.50	2.65	2.30	1.88	2.30	1.92	2.62	2.24	2.65	.84	1.08	.93	.61
		(P_2O_5	.49	.58	.54	.64	.58	.80	.48	.67	.52	.70	.52	.50	.97	.54	.43	.21
-- --	25b	(N																
		(K_2O																
		(P_2O_5																
82- 83	26a	(N	.95	2.07	1.27	2.23	1.44	2.34	1.13	2.58	( )	( )	1.91	3.12	.90	3.10	( )	( )
		(K_2O	3.37	3.43	3.84	3.56	3.93	2.47	3.70	3.03	3.10	3.54	4.36	2.27	3.79	2.45	( )	( )
		(P_2O_5	.94	.72	.97	.74	1.08	.65	.81	.81	.88	1.00	1.34	1.02	1.52	.92	( )	( )
109-110	26b	(N	.94	[b]2.33	.95	2.63	1.25	2.65	1.41	4.15	( )	( )	1.40	3.23	.80	3.40	( )	( )
		(K_2O	2.65	2.38	2.80	2.91	2.30	2.83	2.91	3.86	2.93	3.75	3.59	( )	2.91	( )	( )	( )
		(P_2O_5	.28	.34	.54	.43	.58	.53	.50	.65	.39	.70	.51	( )	1.76	( )	( )	( )

Table 17.-- Continued

87- 88	30a	(N	( )	( )	1.48	2.39	1.22	2.17	1.19	2.63	1.50	( )	1.82	3.12	.83	2.87	1.27	1.90
		(K_2O	( )	( )	2.87	2.30	2.72	1.78	2.52	1.96	2.37	1.87	2.33	3.19	2.09	.91	1.66	.69
		(P_2O_5	( )	( )	.31	.46	.56	.50	.38	.71	.43	.72	.44	1.07	.55	.33	.70	.20
118-119	30b	(N	( )	( )	1.69	2.71	1.45	2.27	1.65	2.39	( )	( )	1.85	3.47	1.11	2.80	( )	( )
		(K_2O	( )	( )	3.39	2.64	3.43	2.40	3.45	2.41	3.80	2.79	2.95	3.38	2.08	1.82	( )	( )
		(P_2O_5	( )	))	.40	.33	.29	.40	.30	.44	.22	.43	.30	.27	.63	.55	( )	( )
90- 91	32a	(N	1.13	[a]1.13	1.15	2.58	.97	2.64	1.22	2.47	1.63	( )	1.50	2.62	1.05	2.96	1.15	1.90
		(K_2O	2.85	3.14	2.81	2.42	3.15	1.45	2.96	1.83	2.74	2.07	1.89	1.38	2.77	.85	1.70	.47
		(P_2O_5	1.02	1.53	1.46	.95	1.56	1.86	1.65	.94	1.75	1.10	1.28	1.22	2.26	.83	.85	.43
121-122	32b	(N	.63	[b]1.74	1.01	2.59	1.22	2.70	.88	2.67	1.03	( )	1.21	3.27	.92	3.17	( )	( )
		(K_2O	2.87	2.40	1.73	2.41	( )	2.10	2.55	3.21	2.53	3.21	2.61	3.69	2.95	1.79	( )	( )
		(P_2O_5	1.20	.79	1.86	.93	2.68	.76	1.62	.90	2.64	1.00	2.19	1.27	1.03	.55	( )	( )
129-130	33a	(N	.76	[b]2.35	.86	2.50	1.61	2.99	1.19	3.27	( )	( )	1.26	3.89	.81	3.15	1.16	( )
		(K_2O	2.94	3.81	2.60	2.93	2.92	3.00	3.48	3.61	3.08	4.00	3.42	3.88	2.82	1.65	1.77	( )
		(P_2O_5	1.18	.55	1.47	.91	1.89	.81	1.92	.95	1.14	.73	2.15	.73	1.08	.55	.77	( )
156-157	37a	(N	( )	( )	( )	( )	2.14	2.37	1.70	3.01	1.89	( )	1.90	4.94	1.58	3.50	1.66	3.14
		(K_2O	( )	( )	( )	( )	4.30	2.83	2.96	2.03	2.31	2.01	2.63	2.35	2.10	1.68	1.37	1.06
		(P_2O_5	( )	( )	( )	( )	.69	.62	.56	.64	.37	.32	.34	( )	.58	.39	.43	.34
158-159	38a	(N	( )	( )	( )	( )	1.70	1.87	1.48	2.99	1.78	( )	1.93	4.74	1.52	2.90	1.64	1.90
		(K_2O	( )	( )	( )	( )	2.76	1.73	1.93	1.92	1.72	1.65	1.79	1.94	.84	1.10	1.05	.53
		(P_2O_5	( )	( )	( )	( )	.94	.82	.88	1.10	.55	.95	.98	( )	.49	.53	.56	.42
160-161	39a	(N	( )	( )	( )	( )	1.56	2.21	1.31	2.70	1.65	( )	1.88	5.58	1.50	4.00	1.67	1.80
		(K_2O	( )	( )	( )	( )	4.00	4.43	2.96	2.61	1.77	2.73	2.38	2.01	1.70	2.05	1.54	1.09
		(P_2O_5	( )	( )	( )	( )	.74	.72	.51	.74	.31	.57	.19	.26	.58	.44	.52	.22

Table 17.-- Continued

162-163	40a	(N	( )	( )	( )	( )	1.55	2.29	1.15	2.54	1.24	1.24	1.69	3.91	1.24	3.32	1.05	2.10
		(K_2O	( )	( )	( )	( )	6.30	3.07	4.53	3.43	4.17	3.28	4.02	3.63	2.70	2.49	2.56	1.36
		(P_2O_5	( )	( )	( )	( )	1.28	.65	1.05	.98	.64	.83	.88	.41	.52	.50	.77	.34
164-165	41a	(N	( )	( )	( )	( )	1.36	1.71	1.21	3.04	( )	( )	1.82	4.89	1.42	2.78	1.73	1.70
		(K_2O	( )	( )	( )	( )	3.18	1.91	1.13	1.74	1.35	1.64	1.72	1.56	.88	1.42	1.20	.54
		(P_2O_5	( )	( )	( )	( )	1.44	.89	( )	1.01	.48	.91	.86	( )	.50	.59	.60	.40
166-167	42a	(N	( )	( )	( )	( )	1.58	2.55	2.96	1.19	1.36	( )	1.57	4.86	1.40	3.34	1.48	1.88
		(K_2O	( )	( )	( )	( )	4.92	3.48	4.48	3.95	3.50	3.88	4.31	3.75	3.36	3.97	2.77	2.80
		(P_2O_5	( )	( )	( )	( )	.79	.71	.52	.75	.38	.70	.37	( )	.48	.39	.46	.20
168-169	43a	(N	( )	( )	( )	( )	1.39	1.52	1.19	2.50	1.04	( )	( )	4.45	.90	3.40	1.00	( )
		(K_2O	( )	( )	( )	( )	5.37	2.92	3.78	2.99	4.06	2.88	4.22	4.10	3.53	2.17	2.80	( )
		(P_2O_5	( )	( )	( )	( )	1.31	.85	1.17	.88	.74	1.26	1.04	.55	1.31	.79	.89	( )
170-171	44a	(N	( )	( )	( )	( )	1.38	2.18	1.19	2.70	1.35	( )	1.66	4.91	1.12	3.50	1.44	( )
		(K_2O	( )	( )	( )	( )	4.37	2.28	2.68	2.30	2.25	2.56	1.42	2.41	2.25	1.73	1.73	( )
		(P_2O_5	( )	( )	( )	( )	.64	.64	.63	.76	.39	.62	.32	( )	.27	.54	.66	( )

a Buckwheat grown
b Clay pots used

Table 18.-- Parts per million of nitrogen, potash, and phosphoric acid taken from cultivated soils by total crops of oats and buckwheat grown in succession.

(a = surface soil; b = subsoil.)

Pot.	Soil No		1895		1896		1897		1898		1899		1900		1901		1902	
			Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat
63	17a	N	( )	a	17	12	10	10	9	9	( )	6	33	7	6	6	6	( )
		K_2O	( )	a	62	25	21	21	21	12	21	8	103	13	25	9	14	( )
		P_2O_5	( )	a	14	9	15	7	8	4	8	3	42	5	13	4	11	( )
93	17b	N	( )	a	8	5	3	6	3	5	4	2	( )	6	3	3	( )	( )
		K_2O	( )	a	37	9	7	13	9	10	9	2	75	11	16	6	( )	( )
		P_2O_5	( )	a	6	3	5	6	4	2	3	1	15	6	6	3	( )	( )
65	18a	N	30	a	8	15	16	16	16	( )	26	( )	58	2	30	( )	7	( )
		K_2O	104	a	15	25	30	26	41	1	30	( )	80	( )	( )	( )	31	( )
		P_2O_5	14	a	5	3	6	3	9	( )	( )	( )	14	( )	( )	( )	7	( )
95	18b	N	12	a	3	4	5	5	4	2	( )	( )	12	2	8	5	9	3
		K_2O	38	a	8	6	6	8	13	3	10	3	28	4	28	7	13	1
		P_2O_5	5	a	2	1	2	1	2	( )	2	( )	5	1	7	4	10	1
69	19a	N	13	a	15	12	10	11	13	5	11	( )	( )	6	24	( )	26	7
		K_2O	32	a	37	6	22	13	26	5	19	1	69	4	26	( )	25	4
		P_2O_5	4	a	4	2	4	1	3	1	3	( )	15	1	8	( )	10	2
101	19b	N	( )	a	4	2	4	2	6	( )	3	( )	21	( )	23	8	21	4
		K_2O	( )	a	10	3	7	4	16	1	11	( )	54	( )	34	28	10	2
		P_2O_5	( )	a	2	( )	1	( )	2	( )	1	( )	9	( )	11	9	6	1

Table 18-- Continued

	(N	32	a	( )	15	16	19	13	14	11	9	59	32	24	2	14	( )		
70	20a (K$_2$O	53	a	( )	32	32	28	26	17	11	8	112	26	68	( )	22	( )		
	(P$_2$O$_5$	15	a	( )	6	7	7	5	3	2	2	21	18	13	( )	10	( )		
	(N	7	a	3	( )	2	5	4	3	( )	( )	124	4	12	7	20	1		
98	20b (K$_2$O	29	a	9	( )	7	9	10	4	5	3	44	7	44	1	32	2		
	(P$_2$O$_5$	3	a	2	( )	1	2	2	( )	1	( )	5	2	5	1	5	( )		
	(N	34	a	13	21	14	17	13	5	13	( )	44	11	33	( )	31	3		
73	21a (K$_2$O	56	a	18	31	17	22	14	5	13	2	43	6	18	( )	25	1		
	(P$_2$O$_5$	9	a	5	5	6	3	4	1	3	( )	6	4	19	( )	16	2		
	(N	14	a	6	6	4	4	7	2	( )	( )	24	8	14	( )	( )	( )		
102	21b (K$_2$O	15	a	12	8	9	6	13	2	4	1	41	8	30	( )	( )	( )		
	(P$_2$O$_5$	2	a	2	1	1	( )	1	( )	( )	( )	7	2	19	( )	( )	( )		
	(N	36	a	25	33	23	34	22	14	17	5	92	12	68	( )	44	3		
74	22a (K$_2$O	58	a	49	42	28	32	30	12	19	5	65	7	45	( )	34	1		
	(P$_2$O$_5$	21	a	11	13	8	9	1	4	5	1	35	5	22	( )	13	1		
	(N	16	a	7	7	8	10	6	7	( )	( )	44	13	14	5	( )	( )		
103	22b (K$_2$O	25	a	15	12	19	16	11	8	15	3	68	16	42	5	( )	( )		
	(P$_2$O$_5$	5	a	4	2	4	3	3	1	4	1	11	6	8	2	( )	( )		
	(N	80	a	26	24	25	29	29	13	34	7	87	18	38	( )	( )	( )		
76	23a (K$_2$O	100	a	98	76	92	65	89	23	83	10	202	34	134	( )	( )	( )		
	(P$_2$O$_5$	20	a	29	15	16	11	11	5	11	2	39	15	27	( )	( )	( )		
	(N	36	a	15	8	7	11	4	5	7	( )	( )	7	23	( )	12	( )		
104	23b (K$_2$O	43	a	45	15	19	14	7	5	14	( )	113	14	68	( )	23	( )		
	(P$_2$O$_5$	7	a	5	2	3	2	( )	1	1	1	14	2	6	( )	11	( )		

Table 18.-- Continued

		(N	18	a	16	17	8	13	9	4	( )	( )	5	1	23	( )	( )	( )
106	24a	(K_2O	16	a	17	15	5	8	4	3	6	2	5	( )	34	( )	( )	( )
		(P_2O_5	6	a	10	4	3	2	2	1	2	( )	1	( )	4	( )	( )	( )
		(N	25	a	1	2	1	3	4	4	1	( )	1	5	13	( )	21	( )
78	24b	(K_2O	17	a	1	5	3	8	7	6	2	1	( )	7	24	( )	39	( )
		(P_2O_5	7	a	1	1	1	1	2	1	2	( )	( )	2	5	( )	8	( )
		(N	22	a	24	22	20	20	18	5	17	( )	33	16	37	4	29	2
80	25a	(K_2O	39	a	53	46	34	32	23	5	19	1	33	12	20	2	17	1
		(P_2O_5	5	a	10	8	8	( )	6	1	5	( )	8	6	24	2	8	( )
		(N	( )	a	4	5	3	3	4	3	( )	( )	12	4	12	4	( )	( )
108	25b	(K_2O	( )	a	11	10	7	9	10	5	6	2	28	9	36	4	( )	( )
		(P_2O_5	( )	a	2	1	1	1	2	( )	2	( )	5	2	17	2	( )	( )
		(N	25	a	35	36	26	24	17	12	( )	( )	63	17	17	7	( )	( )
82	26a	(K_2O	88	a	106	75	70	37	56	16	44	12	145	34	71	2	( )	( )
		(P_2O_5	24	a	27	14	19	8	12	4	12	3	45	19	29	1	( )	( )
		(N	11	a	5	3	4	4	6	1	( )	( )	22	( )	9	( )	( )	( )
109	26b	(K_2O	32	a	14	5	8	5	12	2	15	1	56	( )	32	( )	( )	( )
		(P_2O_5	3	a	3	1	2	1	2	( )	2	( )	8	( )	19	( )	( )	( )
		(N	( )	a	15	15	12	14	9	9	6	4	36	11	9	( )	5	( )
84	27a	(K_2O	( )	a	46	30	28	9	18	16	16	5	112	18	45	( )	13	2
		(P_2O_5	( )	a	12	9	8	4	8	4	7	1	25	8	13	( )	4	1
		(N	( )	a	3	4	2	2	5	1	( )	( )	10	4	6	( )	( )	( )
111	27b	(K_2O	( )	a	10	6	7	3	15	1	11	1	26	8	35	( )	( )	( )
		(P_2O_5	( )	a	2	1	1	( )	2	( )	1	( )	3	2	4	( )	( )	( )

Table 18.-- Continued

	(N	( )	a	13	21	13	41	13	10	14	2	( )	7	22	( )	22	2			
85	28a(K_2O	( )	a	34	46	22	41	15	13	21	3	79	5	38	( )	25	1			
	(P_2O_5	( )	a	11	13	4	11	4	3	4	1	40	3	19	( )	14	1			
	(N	17	a	4	5	3	13	3	4	1	5	19	5	16	( )	( )	( )			
112	28b(K_2O	54	a	10	9	7	13	4	8	2	7	38	9	51	( )	( )	( )			
	(P_2O_5	7	a	5	3	3	6	1	2	1	1	22	5	20	( )	( )	( )			
	(N	( )	a	36	22	16	19	19	18	24	5	54	11	18	2	( )	( )			
86	29a(K_2O	( )	a	99	58	40	55	49	23	49	5	82	8	57	( )	( )	( )			
	(P_2O_5	( )	a	27	17	24	17	26	7	27	1	46	8	23	( )	( )	( )			
	(N	( )	a	17	6	6	9	6	3	8	( )	27	2	11	( )	( )	( )			
113	29b(K_2O	( )	a	53	7	14	16	27	2	16	( )	56	2	34	( )	( )	( )			
	(P_2O_5	( )	a	8	3	5	2	4	1	3	( )	26	1	12	( )	( )	( )			
	(N	( )	a	24	21	11	18	9	12	12	9	65	23	14	8	10	3			
87	30a(K_2O	( )	a	46	32	24	22	20	13	19	9	83	24	34	3	13	1			
	(P_2O_5	( )	a	5	6	5	4	3	2	3	2	16	12	9	1	6	1			
	(N	( )	a	10	7	14	4	14	1	( )	( )	14	10	29	4	( )	( )			
118	30b(K_2O	( )	a	21	7	32	4	28	1	15	1	22	11	54	6	( )	( )			
	(P_2O_5	( )	a	3	1	3	( )	2	( )	1	( )	2	3	15	3	( )	( )			
	(N	43	a	16	12	12	15	9	2	7	( )	37	2	17	( )	28	1			
89	31a(K_2O	56	a	31	25	30	25	12	2	10	( )	64	2	12	( )	15	( )			
	(P_2O_5	13	a	4	2	3	3	3	( )	2	( )	8	( )	26	( )	14	( )			
	(N	40	a	7	5	4	8	8	7	( )	( )	19	3	32	14	( )	( )			
120	31b(K_2O	48	a	11	10	7	14	15	11	5	2	51	3	45	8	( )	( )			
	(P_2O_5	9	a	5	1	2	2	3	1	1	( )	12	1	11	6	( )	( )			

Table 18.-- Continued

		(N	29	a	16	20	12	24	17	7	16	14	57	20	17	13	19	4
90	32a	(K_2O	72	a	39	44	38	36	41	17	27	12	72	27	45	15	28	2
		(P_2O_5	26	a	20	15	19	16	23	7	9	6	48	13	37	10	14	1
		(N	9	a	3	4	3	5	2	3	2	3	16	5	14	( )	( )	( )
121	32b	(K_2O	43	a	5	11	( )	7	7	7	5	5	38	9	46	( )	( )	( )
		(P_2O_5	18	a	5	4	6	5	4	2	6	2	29	7	16	( )	( )	( )
		(N	7	a	4	8	5	8	4	4	( )	( )	22	4	13	( )	26	2
129	33a	(K_2O	27	a	13	16	9	16	13	6	14	3	59	7	47	( )	40	1
		(P_2O_5	11	a	7	6	6	6	7	2	5	1	37	2	18	( )	17	1
		(N	13	a	13	10	10	4	12	( )	11	( )	31	( )	36	11	34	2
29	34a	(K_2O	24	a	15	15	17	5	19	1	14	( )	38	( )	25	7	26	1
		(P_2O_5	4	a	6	2	5	1	5	( )	4	( )	8	( )	10	4	9	( )
		(N	86	a	31	32	23	31	23	11	19	7	52	16	23	9	7	( )
131	35a	(K_2O	112	a	51	42	22	18	14	4	14	4	35	24	23	5	9	( )
		(P_2O_5	29	a	29	18	20	11	7	3	5	1	24	10	12	4	4	( )
		(N	( )	a	( )	( )	11	( )	14	5	( )	( )	39	16	16	6	( )	( )
151	36a	(K_2O	( )	a	( )	( )	36	( )	35	5	29	4	83	25	49	7	( )	( )
		(P_2O_5	( )	a	( )	( )	7	( )	6	1	4	( )	12	12	9	2	( )	( )
		(N	( )	a	( )	( )	11	15	12	3	17	1	31	6	6	( )	17	1
156	37a	(K_2O	( )	a	( )	( )	21	16	21	3	21	1	43	7	9	( )	14	1
		(P_2O_5	( )	a	( )	( )	3	3	4	1	3	( )	6	2	2	( )	4	( )

Table 18.-- Continued

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Table 19.-- Parts per million of nitrogen, potash, and phosphoric acid taken from cultivated soils by total crops of beans and buckwheat grown in succession.
(Cowpeas grown instead of beans in 1901, 1902.)

(a = surface soil; b = subsoil.)

Pot	Soil No		1895		1896		1897		1898		1899		1900		1901		1902	
			Beans	Buckwheat	Beans	Buckwheat	Beans	Buckwheat	Beans	Buckwheat	Beans	Buckwheat	Beans	Buckwheat	Cowpeas	Buckwh.	Cowpeas	Buckwheat
64	17a	(N	( )	a	24	13	47	15	25	12	( )	( )	46	14	158	( )	146	
		(K_2O	( )	a	30	30	41	36	33	24	40	12	39	24	129	( )	79	
		(P_2O_5	( )	a	8	9	13	12	10	6	9	4	27	16	29	( )	19	
94	17b	(N	( )	a	19	7	27	13	20	7	( )	( )	27	11	96	( )	( )	
		(K_2O	( )	a	21	16	22	( )	20	12	21	6	31	20	66	( )	( )	
		(P_2O_5	( )	a	5	5	8	( )	6	4	6	2	7	8	17	( )	( )	
67	18a	(N	34	a	14	9	15	22	13	2	( )	( )	5	( )	85	22	220	
		(K_2O	65	a	15	13	16	32	9	2	6	( )	2	( )	68	( )	84	
		(P_2O_5	16	a	3	2	2	6	2	( )	2	( )	1	( )	16	10	30	
96	18b	(N	18	a	9	7	9	8	16	5	( )	( )	( )	9	86	( )	163	
		(K_2O	22	a	11	14	14	11	14	7	10	3	4	7	92	( )	62	
		(P_2O_5	4	a	2	2	2	2	3	1	2	( )	1	1	17	( )	38	
71	20a	(N	46	a	30	21	41	33	31	15	( )	( )	89	19	106	( )	63	
		(K_2O	39	a	22	38	25	49	22	23	24	13	86	22	53	( )	22	
		(P_2O_5	15	a	9	7	8	1	9	4	9	3	14	13	23	( )	9	
99	20b	(N	21	a	( )	5	20	10	18	5	( )	( )	20	6	57	( )	27	
		(K_2O	26	a	( )	8	17	( )	21	8	26	5	24	7	52	( )	28	
		(P_2O_5	5	a	( )	2	3	( )	4	2	4	1	4	2	3	( )	8	

Table 19.-- Continued

| | | |

Table 19.-- Continued

	(N	69	a	45	57	54	37	44	12	( )	( )	104	19	141	( )	( )				
83:	26a (K2O	97	a	72	77	57	66	51	16	49	6	76	30	111	( )	( )				
	(P2O5	20	a	15	16	15	16	14	4	14	2	34	17	42	( )	( )				
	(N	35	c a	21	5	13	10	17	2	( )	( )	1	12	( )	( )	( )				
110:	26b (K2O	36	a	23	11	14	12	15	2	13	2	( )	9	( )	( )	( )				
	(P2O5	8	a	3	1	3	1	3	( )	2	( )	( )	1	( )	( )	( )				
	(N	( )	a	27	20	24	21	18	14	( )	( )	52	21	134	( )	90				
88:	30a (K2O	( )	a	26	37	20	31	13	13	15	4	53	25	42	( )	33				
	(P2O5	( )	a	5	6	6	4	5	3	6	1	18	10	15	( )	9				
	(N	( )	a	26	14	26	14	30	8	( )	( )	25	15	93	( )	( )				
119:	30b (K2O	( )	a	25	20	27	17	30	10	20	2	24	20	60	( )	( )				
	(P2O5	( )	a	3	3	4	3	5	1	3	( )	2	5	18	( )	( )				
	(N	b 13	a	37	24	44	31	38	16	( )	( )	65	21	146	( )	129				
91:	32a (K2O	34	a	34	47	24	45	28	18	25	13	34	30	42	( )	32				
	(P2O5	17	a	14	15	31	22	15	7	14	6	30	25	41	( )	29				
	(N	c 18	a	20	6	36	12	18	5	( )	( )	14	13	134	( )	( )				
122:	32b (K2O	25	a	19	13	28	24	22	12	16	9	16	16	76	( )	( )				
	(P2O5	8	a	7	4	10	7	6	3	5	3	6	11	23	( )	( )				
	(N	c 29	a	18	11	17	11	20	6	( )	( )	14	8	102	( )	( )				
130:	33a (K2O	34	a	21	22	17	24	22	10	14	5	14	11	53	( )	( )				
	(P2O5	7	a	6	6	5	10	6	2	3	1	3	4	18	( )	( )				
	(N	( )	a	16	13	11	7	12	( )	( )	( )	( )	d ( )	5	11	29				
30:	34a (K2O	( )	a	17	22	10	9	9	1	5	( )	( )	d ( )	( )	9	28				
	(P2O5	( )	a	3	3	2	1	2	( )	1	( )	( )	d ( )	( )	4	4				

Table 19.-- Continued

| | | |

Table 19.-- Continued

	(N	( )	a	( )	( )	17	14	25	8	( )	( )	11	( )	17	( )	( )		
171	44a(K_2O	( )	a	( )	( )	17	23	21	9	17	4	6	( )	8	5	( )		
	(P_2O_5	( )	a	( )	( )	5	4	7	1	4	1	( )	( )	3	1	( )		

a Not planted
b Buckwheat grown
c Clay pots used
d Cowpeas.

Table 20.-- Comparison of number of parts per million of nitrogen, potash, and phosphoric acid taken from the same cultivated soils by total crops of oats and beans. (Cowpeas grown instead of beans in 1901, 1902.)

(a = surface soil; b = subsoil.)

Pot	Soil No		1895		1896		1897		1898		1899		1900		1901		1902	
			Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Beans	Oats	Cow-peas	Oats	Cow-peas
63-64	17a	(N	( )	( )	17	24	10	47	9	25	10	( )	33	46	6	158	6	146
		(K_2O	( )	( )	62	30	21	41	21	33	21	40	103	39	25	129	14	79
		(P_2O_5	( )	( )	14	8	15	13	8	10	8	9	42	27	13	29	11	19
93-94	17b	(N	( )	( )	8	19	3	27	3	20	4	( )	( )	27	3	96	( )	( )
		(K_2O	( )	( )	37	21	7	22	9	20	9	21	75	31	16	66	( )	( )
		(P_2O_5	( )	( )	6	5	5	8	4	6	3	6	15	7	6	17	( )	( )
65-67	18a	(N	30	34	8	14	16	15	16	13	26	( )	58	5	30	85	7	220
		(K_2O	104	65	15	15	36	16	41	9	35	6	85	2	( )	68	31	84
		(P_2O_5	14	16	5	3	6	2	9	2	( )	2	14	1	( )	16	7	30
95-96	18b	(N	12	18	3	9	5	9	4	16	( )	( )	12	( )	8	86	9	163
		(K_2O	38	22	8	11	6	14	13	14	10	10	28	4	28	92	13	62
		(P_2O_5	5	4	2	2	2	2	2	3	2	2	5	1	7	17	10	38
70-71	20a	(N	32	46	( )	30	14	41	13	31	11	( )	59	89	24	106	14	63
		(K_2O	53	39	( )	22	28	25	22	22	11	24	112	86	68	53	22	22
		(P_2O_5	15	15	( )	9	7	8	5	9	2	9	21	14	13	23	10	9
98-99	20b	(N	( )	( )	3	( )	2	20	4	18	( )	( )	134	20	12	57	20	27
		(K_2O	( )	( )	9	( )	7	17	10	21	5	26	44	24	44	52	32	28
		(P_2O_5	( )	( )	2	( )	1	3	2	4	1	4	5	4	5	3	5	8

Table 20.-- Continued

74- 75	22a	(N	( )	( )	25	( )	23	70	22	56	17	( )	92	110	68	134	44	143
		(K_2O	( )	( )	49	( )	28	50	30	36	19	34	65	38	45	56	34	48
		(P_2O_5	( )	( )	11	( )	8	19	1	19	5	14	35	22	22	26	13	27
-- --	22b	(N																
		(K_2O																
		(P_2O_5																
106-107	24a	(N	( )	( )	16	22	8	15	9	18	( )	( )	5	( )	23	11	( )	( )
		(K_2O	( )	( )	17	10	5	7	4	8	6	( )	5	( )	34	11	( )	( )
		(P_2O_5	( )	( )	10	7	3	3	2	3	2	( )	1	( )	4	1	( )	( )
78- 79	24b	(N	( )	( )	1	7	1	16	4	13	1	( )	1	( )	13	47	21	43
		(K_2O	( )	( )	1	5	3	9	7	10	2	11	( )	( )	24	30	39	29
		(P_2O_5	( )	( )	1	2	1	2	2	5	2	3	( )	( )	5	5	8	7
80- 81	25a	(N	( )	( )	24	28	20	35	18	36	17	( )	33	23	37	59	29	96
		(K_2O	( )	( )	53	29	34	32	23	28	19	21	33	13	20	24	17	29
		(P_2O_5	( )	( )	10	7	8	11	6	8	5	5	8	3	24	12	8	10
-- --	25b	(N																
		(K_2O																
		(P_2O_5																
82- 83	26a	(N	( )	( )	35	45	26	54	17	44	( )	( )	63	104	17	141	( )	( )
		(K_2O	( )	( )	106	72	70	57	56	51	44	49	145	76	71	111	( )	( )
		(P_2O_5	( )	( )	27	15	19	15	12	14	12	14	45	34	29	42	( )	( )
109-110	26b	(N	( )	( )	5	21	4	13	6	17	( )	( )	22	( )	9	( )	( )	( )
		(K_2O	( )	( )	14	33	8	14	12	15	15	13	56	( )	32	( )	( )	( )
		(P_2O_5	( )	( )	3	3	2	3	2	3	2	2	8	( )	10	( )	( )	( )

Table 20.— Continued

87- 88	30a	(N	( )	( )	24	27	11	24	9	18	12	( )	65	52	14	134	10	90
		(K_2O	( )	( )	46	26	24	20	20	13	19	15	83	53	34	42	13	33
		(P_2O_5	( )	( )	5	5	5	6	3	5	3	6	16	18	9	15	6	9
118-119	30b	(N	( )	( )	10	26	14	26	14	30	( )	( )	14	25	29	93	( )	( )
		(K_2O	( )	( )	21	28	32	27	28	30	15	20	22	24	54	60	( )	( )
		(P_2O_5	( )	( )	3	3	3	4	2	5	1	3	2	2	15	18	( )	( )
90- 91	32a	(N	( )	( )	16	37	12	44	17	38	16	( )	57	( )	17	146	19	129
		(K_2O	( )	( )	39	34	38	24	41	28	27	25	72	( )	45	42	28	32
		(P_2O_5	( )	( )	20	14	19	31	23	15	9	14	48	( )	37	41	14	29
121-122	32b	(N	( )	( )	3	20	3	36	2	18	2	( )	16	14	14	134	( )	( )
		(K_2O	( )	( )	5	19	( )	28	7	22	5	16	38	16	46	78	( )	( )
		(P_2O_5	( )	( )	6	7	6	10	4	6	6	5	29	6	16	23	( )	( )
129-130	33a	(N	( )	( )	4	18	5	17	4	20	( )	( )	22	14	13	102	26	( )
		(K_2O	( )	( )	13	21	9	17	13	22	14	14	59	14	47	53	40	( )
		(P_2O_5	( )	( )	7	6	6	5	7	6	5	3	37	3	18	18	17	( )
156-157	37a	(N	( )	( )	( )	( )	11	18	12	23	17	( )	31	13	6	6	17	150
		(K_2O	( )	( )	( )	( )	21	21	21	15	21	13	43	6	9	3	14	51
		(P_2O_5	( )	( )	( )	( )	3	5	4	5	3	2	6	( )	2	1	4	16
158-159	38a	(N	( )	( )	( )	( )	19	25	13	31	27	( )	47	13	26	69	29	63
		(K_2O	( )	( )	( )	( )	30	23	18	20	26	17	43	6	14	26	19	18
		(P_2O_5	( )	( )	( )	( )	10	11	8	11	8	10	23	( )	8	13	10	14

Table 20.-- Continued

160-161	39a	(N	( )	( )	( )	( )	9	17	10	22	16	( )	31	6	14	9	18	104
		(K_2O	( )	( )	( )	( )	24	33	24	21	18	23	39	2	16	5	17	63
		(P_2O_5	( )	( )	( )	( )	4	5	4	6	3	5	3	( )	6	1	6	13
162-163	40a	(N	( )	( )	( )	( )	19	30	13	23	21	16	56	26	30	109	19	78
		(K_2O	( )	( )	( )	( )	76	40	50	31	71	42	132	24	64	82	45	50
		(P_2O_5	( )	( )	( )	( )	15	8	12	9	11	11	29	3	12	16	14	13
164-165	41a	(N	( )	( )	( )	( )	12	21	11	27	14	( )	37	7	20	52	26	58
		(K_2O	( )	( )	( )	( )	29	23	10	16	16	19	35	2	12	26	18	18
		(P_2O_5	( )	( )	( )	( )	13	11	( )	9	6	11	17	( )	7	11	9	14
166-167	42a	(N	( )	( )	( )	( )	11	18	22	10	14	( )	33	16	14	9	26	88
		(K_2O	( )	( )	( )	( )	34	25	49	34	35	32	66	12	35	11	49	141
		(P_2O_5	( )	( )	( )	( )	6	5	6	7	4	6	5	( )	5	1	8	10
168-169	43a	(N	( )	( )	( )	( )	17	19	12	32	15	( )	( )	28	18	( )	16	( )
		(K_2O	( )	( )	( )	( )	64	37	38	38	57	36	139	26	71	( )	45	( )
		(P_2O_5	( )	( )	)	( )	16	11	12	11	10	16	34	4	26	( )	14	( )
170-171	44a	(N	( )	( )	( )	( )	10	17	10	25	14	( )	41	11	14	17	12	( )
		(K_2O	( )	( )	( )	( )	30	17	21	21	22	17	35	6	28	8	14	( )
		(P_2O_5	( )	( )	( )	( )	4	5	5	7	4	4	8	( )	3	3	5	( )

Table 21.— Total crop yields of oats and buckwheat grown in succession on Florida muck soils.

(a = surface soil; b = subsoil.)

Pot No.	Soil No.	1895		1896		1897		1898		1899		1900		1901		1902	
		Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat
		grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams
135	45a	[a] 5.6	[a] 5.0	25.1	1.6	15.1	0.7	7.0	0.4	11.3	( )	21.7	( )	11.7	0.5	2.0	( )
136	45a	[a] 37.9	[a] 2.0	43.4	18.6	19.9	12.4	6.8	0.3	13.0	( )	28.6	( )	35.9	0.6	38.2	( )
137	45a	[a] 51.4	[a] 10.0	31.2	19.5	20.4	8.3	11.1	0.4	14.2	0.1	26.4	( )	27.8	1.1	21.5	( )
138	45a	[a] 43.6	[a] 10.6	32.9	10.7	20.8	1.2	11.3	0.5	14.6	( )	25.0	( )	30.9	0.9	30.2	( )
139	46a	[a] 14.7	[a] 10.0	17.6	2.8	13.5	1.8	8.0	0.4	25.4	0.1	17.0	( )	10.2	( )	15.7	1.4
140	46a	[a] 33.0	[a] 1.0	42.3	20.6	24.8	12.2	13.3	4.2	22.0	2.5	28.0	1.6	46.2	7.2	32.6	2.5
141	46a	[a] 56.7	[a] 1.0	46.4	24.2	27.9	14.9	13.8	6.2	23.0	4.6	33.6	11.3	19.3	6.2	50.0	3.0
142	46a	[a] 52.0	[a] 13.5	46.4	21.6	25.2	17.2	10.6	9.1	19.9	2.9	23.6	12.7	15.7	6.8	47.2	2.7
143	47a	[a] 29.3	[a] 15.8	36.1	17.8	23.7	13.2	11.6	4.8	17.9	1.9	26.9	2.2	45.0	3.8	45.2	1.0
144	48a	[a] 55.8	[a] 15.0	53.2	21.3	23.6	16.2	12.7	7.8	16.4	3.2	31.4	5.9	37.6	6.1	34.1	1.9
145	48a	[a] 47.2	[a] 16.7	34.4	25.4	22.1	11.6	14.8	7.0	15.1	5.8	23.4	8.3	19.3	8.5	16.6	1.1
146	48a	[a] 34.0	[a] 19.0	29.9	14.7	18.2	9.8	12.5	6.2	9.1	2.8	26.2	6.0	20.8	5.8	17.0	1.9

a Clay pots used

Table 22.-- Nitrogen, potash, and phosphoric acid content of total crops of oats and buckwheat grown in succession on Florida muck soils.

(a = surface soil; b = subsoil.)

Pot	Soil No		1895		1896		1897		1898		1899		1900		1901		1902	
			Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
135	45a	(N	[a]1.45	[a]2.08	1.87	3.53	2.29	( )	2.87	( )	( )	( )	3.26	( )	3.54	( )	3.33	( )
		(K_2O	2.79	2.96	2.35	2.67	2.86	1.42	2.33	3.98	1.45	( )	1.20	( )	1.36	( )	.66	( )
		(P_2O_5	.28	.30	.34	.35	.40	( )	.34	.43	.91	( )	.40	( )	.39	( )	.59	( )
136	45a	(N	[a].97	[a]2.66	1.64	2.32	1.79	2.79	2.74	( )	( )	( )	2.83	( )	2.52	( )	2.26	( )
		(K_2O	2.55	1.20	1.81	2.01	.94	1.34	.98	.88	.62	( )	.82	( )	.83	( )	.60	( )
		(P_2O_5	.76	.30	.43	.55	.48	.43	.41	.40	.87	( )	.39	( )	.30	( )	.43	( )
137	45a	(N	[a]1.12	[a]1.65	1.18	2.02	1.55	2.78	2.65	( )	( )	( )	2.42	( )	2.16	( )	2.17	( )
		(K_2O	1.44	2.43	1.34	1.55	.68	1.52	.66	1.38	1.17	( )	.90	( )	.79	( )	.66	( )
		(P_2O_5	.86	.95	1.05	.76	.48	.64	.33	.10	.52	( )	.36	( )	.53	( )	.96	( )
138	45a	(N	[a]1.22	[a]2.02	1.35	2.92	1.71	( )	2.78	( )	( )	( )	2.57	( )	2.41	( )	2.26	3.43
		(K_2O	2.26	2.90	1.53	2.33	.57	1.40	1.06	2.36	2.06	( )	.80	( )	.78	( )	.68	1.31
		(P_2O_5	.50	1.01	1.02	.75	.43	.52	.27	.60	.58	( )	.42	( )	.33	( )	.76	1.60
139	46a	(N	[a]1.92	[a]2.55	2.23	2.86	2.53	( )	2.35	( )	( )	( )	3.16	( )	3.74	( )	2.16	3.47
		(K_2O	3.34	3.97	3.00	2.67	3.28	2.69	2.71	1.46	1.52	( )	1.85	( )	1.41	( )	1.64	2.09
		(P_2O_5	.33	.32	.29	.33	.31	1.07	.66	.05	.48	( )	.30	( )	.39	( )	.29	.30

Table 22.-- Continued

	(N	[a]2.26	[a]3.14	1.97	3.38	2.11	2.70	2.31	2.99	( )	( )	3.05	3.19	1.94	2.18	2.24	2.78
140	46a (K2O	2.40	3.79	1.54	1.26	.81	.99	.66	3.93	.42	2.57	.65	2.86	1.28	1.56	1.76	1.91
	(P2O5	.68	1.50	.40	.40	.41	.54	.39	.50	.81	.54	.29	1.59	.29	.43	.54	.47
	(N	[a]2.35	[a]2.69	1.94	3.48	2.09	3.65	2.11	2.78	( )	( )	2.65	3.02	1.80	2.27	2.26	3.34
141	46a (K2O	2.53	2.95	1.92	1.10	.77	.65	.48	1.16	.89	2.12	.56	1.30	1.54	1.29	.72	2.67
	(P2O5	.72	1.01	.38	.27	.39	.45	.40	.57	.35	.55	.26	.72	.21	.48	.43	.64
	(N	[a]2.07	[a]2.10	1.93	2.48	1.92	2.27	2.51	2.81	( )	( )	2.56	2.91	1.70	2.00	2.35	3.20
142	46a (K2O	2.32	2.44	1.24	.94	.72	.62	.55	1.19	1.17	2.13	1.03	1.25	1.84	1.15	.79	1.97
	(P2O5	.50	.34	.39	.32	.32	.37	.45	.51	.35	.35	.24	.55	.35	.47	.69	1.15
	(N	[a]1.10	[a]1.37	1.22	2.53	1.72	2.96	2.45	2.83	( )	( )	2.96	4.09	2.16	2.58	2.46	3.50
143	47a (K2O	1.53	1.50	.80	.94	.61	.71	.45	1.25	.54	2.12	.74	1.26	1.04	( )	.86	2.21
	(P2O5	.41	.47	.48	.65	.44	.75	.28	.73	.31	.47	.36	1.39	.32	( )	1.08	1.31
	(N	[a]1.07	[a]1.49	1.11	1.84	1.39	2.78	2.07	2.96	( )	( )	2.78	3.00	2.18	2.40	1.88	3.56
144	48a (K2O	1.21	1.88	1.21	.87	.71	.67	.57	1.29	1.20	1.72	.66	1.47	.94	( )	1.73	2.45
	(P2O5	1.20	1.39	1.03	.89	.84	1.09	.57	.83	.52	.51	.39	1.28	.37	( )	.49	.40
	(N	[a]1.04	[a]1.60	1.05	2.11	1.72	3.39	2.46	3.38	( )	( )	3.09	3.16	2.30	2.55	2.68	3.46
145	48a (K2O	1.42	1.18	.86	.69	.40	.41	1.98	.74	.38	1.10	3.53	.92	.44	.85	.68	1.93
	(P2O5	1.35	1.50	1.12	.99	.90	1.14	.73	.93	.63	.83	.49	1.03	.55	.63	.31	.53
	(N	[a] .77	[a]1.29	1.18	3.12	2.13	3.78	2.52	2.31	( )	( )	3.15	2.77	2.70	2.44	2.88	3.72
146	48a (K2O	1.44	1.24	.77	.61	.43	.56	3.36	2.06	.36	1.15	( )	.94	.47	.98	.57	1.15
	(P2O5	1.21	1.35	1.44	1.35	1.47	1.19	1.13	.70	.78	.77	.47	1.22	.61	.66	.59	.42

a Clay pots used

Table 23.— Parts per million of nitrogen, potash, and phosphoric acid taken from the soil by total crops of oats and buckwheat; grown in succession on Florida muck soils.

(a = surface soil; b = subsoil.)

Pot	Soil No	1895		1896		1897		1898		1899		1900		1901		1902	
		Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat
135	45a (N	a 23	a 30	67	8	49	( )	29	( )	( )	( )	101	( )	59	( )	10	( )
	(K$_2$O	44	42	84	6	62	1	23	2	23	( )	37	( )	23	( )	2	( )
	(P$_2$O$_5$	4	4	12	1	9	( )	3	( )	15	( )	12	( )	7	( )	2	( )
136	45a (N	a 105	a 15	108	65	54	52	28	( )	( )	( )	133	( )	137	( )	124	( )
	(K$_2$O	276	7	119	67	28	25	10	( )	12	( )	36	( )	45	( )	30	( )
	(P$_2$O$_5$	82	2	28	16	13	8	4	( )	17	( )	17	( )	15	( )	24	( )
137	45a (N	a 164	a 47	69	74	60	28	56	( )	( )	( )	120	( )	113	( )	88	( )
	(K$_2$O	211	69	79	57	26	15	14	1	31	( )	45	( )	42	( )	27	( )
	(P$_2$O$_5$	126	27	62	28	18	6	7	( )	14	( )	18	( )	28	( )	39	( )
138	45a (N	a 150	a 61	84	59	67	( )	59	( )	( )	( )	121	( )	141	( )	86	( )
	(K$_2$O	281	88	95	47	22	3	23	2	57	( )	38	( )	55	( )	24	( )
	(P$_2$O$_5$	101	30	63	15	17	1	6	1	16	( )	20	( )	19	( )	67	( )
139	46a (N	a 20	a 70	58	13	50	( )	28	( )	( )	( )	79	( )	56	( )	50	7
	(K$_2$O	140	80	78	11	65	7	32	1	57	( )	46	( )	21	( )	38	4
	(P$_2$O$_5$	14	9	8	1	6	3	8	( )	18	( )	8	( )	6	( )	7	1

Table 23,-- Continued

	(N	[a]	342	[a]	1	132	78	83	52	60	20	( )	( )	136	8	142	25	116	11
140	46a(K_2O		363		1	103	41	32	19	17	26	15	10	29	7	94	18	91	8
	(P_2O_5		103		1/2	27	13	16	10	10	3	3	2	13	4	21	5	28	2
	(N	[a]	381	[a]	1	145	97	94	64	47	37	( )	( )	101	55	56	23	182	16
141	46a(K_2O		410		1	144	43	35	16	11	15	33	23	21	24	48	16	58	13
	(P_2O_5		117		1/2	28	11	18	11	9	8	13	6	10	13	6	5	34	3
	(N	[a]	307	[a]	81	153	88	79	64	44	42	( )	( )	99	61	52	22	182	14
142	46a(K_2O		345		94	98	33	30	17	10	18	38	10	40	26	54	13	61	9
	(P_2O_5		74		13	31	11	13	10	8	8	11	2	9	11	11	5	53	6
	(N	[a]	84	[a]	62	60	61	55	53	38	18	( )	( )	108	12	131	13	150	5
143	47a(K_2O		128		68	39	23	20	13	7	8	13	5	27	4	63	( )	52	3
	(P_2O_5		34		31	23	16	14	13	4	5	8	1	13	4	20	( )	66	2
	(N	[a]	170	[a]	64	57	58	48	66	39	34	( )	( )	128	26	121	22	94	10
144	48a(K_2O		193		80	63	27	25	16	11	15	29	8	30	13	52	( )	87	7
	(P_2O_5		190		60	53	28	29	26	11	10	13	2	18	11	20	( )	25	1
	(N	[a]	140	[a]	76	53	79	56	68	54	35	( )	( )	106	44	65	24	65	6
145	48a(K_2O		191		56	44	26	13	7	42	6	8	9	121	9	12	8	17	3
	(P_2O_5		182		71	57	37	29	19	16	10	14	7	17	10	16	6	8	1
	(N	[a]	120	[a]	70	54	71	60	37	48	22	( )	( )	127	21	86	22	75	11
146	48a(K_2O		224		67	35	14	12	8	65	20	5	5	( )	7	15	9	15	3
	(P_2O_5		189		73	66	31	41	18	22	7	11	3	19	9	19	6	15	4

a Clay pots used

Table 24.-- Total crop yields of oats and buckwheat grown in succession and in duplicate pots.

(a = surface soil; b = subsoil.)

Pot No:	Soil No:	1896		1897		1898		1899		1900		1901		1902	
		Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat
		grams:	grams:	grams:	grams:	grams:	grams:	grams:	grams:	grams:	grams:	grams:	grams:	grams:	grams:
29)	34a	28.7:	13.3:	19.2:	4.0:	22.6:	0.8:	19.7:	0.6:	35.7:	( ):	53.2:	13.8:	48.4:	1.8:
62)		20.3:	17.9:	16.9:	16.2:	17.4:	3.9:	16.7:	1.3:	38.6:	( ):	48.4:	1.4:	54.2:	( ):
92)		25.4:	20.2:	21.6:	13.7:	27.1:	3.1:	18.6:	1.2:	44.2:	( ):	51.1:	0.4:	( ):	( ):
123)		22.4:	18.6:	17.9:	12.4:	22.0:	3.3:	24.2:	1.8:	42.0:	( ):	33.2:	0.4:	30.2:	2.2:
35)	3b	8.1:	3.9:	6.3:	3.9:	5.4:	1.6:	6.9:	0.8:	30.1:	12.3:	72.8:	17.4:	37.3:	5.8:
57)		7.9:	3.5:	3.2:	5.5:	5.1:	1.7:	4.8:	1.7:	24.8:	9.9:	44.6:	4.9:	11.3:	0.9:
41)	6b	9.0:	10.5:	12.7:	11.4:	10.0:	3.3:	8.6:	1.4:	49.4:	12.3:	69.0:	17.7:	( ):	( ):
43)		13.0:	10.0:	12.5:	8.5:	8.8:	1.6:	8.1:	1.0:	50.9:	9.2:	64.6:	3.2:	( ):	( ):
55)	13b	16.7:	10.8:	8.7:	8.3:	11.3:	3.7:	13.8:	2.1:	13.2:	9.7:	8.5:	3.5:	( ):	( ):
57)		14.2:	4.7:	10.4:	8.8:	12.0:	3.3:	11.0:	1.4:	6.8:	9.8:	6.6:	4.7:	( ):	( ):
65)	18a	14.5:	14.3:	25.2:	14.0:	24.0:	0.7:	29.4:	0.2:	56.3:	( ):	52.4:	0.2:	24.4:	( ):
66)		18.0:	14.1:	25.8:	16.0:	25.4:	0.6:	25.8:	0.1:	60.7:	1.1:	62.6:	0.4:	51.7:	6.7:
70)	20a	( ):	24.0:	23.0:	22.6:	16.0:	14.7:	9.9:	8.6:	86.3:	30.0:	59.3:	2.1:	25.7:	2.3:
72)		19.6:	19.8:	18.7:	25.9:	15.2:	16.5:	19.6:	8.8:	83.1:	20.1:	44.7:	10.5:	18.5:	0.4:
95)	18b	7.8:	3.7:	9.9:	3.7:	10.1:	2.1:	10.0:	1.6:	24.5:	3.3:	24.3:	7.4:	18.8:	1.1:
97)		8.8:	7.8:	9.8:	13.4:	10.6:	3.0:	8.9:	1.0:	34.9:	9.9:	12.3:	( ):	43.0:	0.4:
98)	20b	7.1:	( ):	4.2:	8.2:	6.3:	3.0:	3.8:	2.7:	27.6:	8.2:	29.4:	8.2:	29.8:	1.3:
100)		4.1:	3.7:	3.9:	8.4:	2.3:	4.1:	6.0:	4.4:	77.7:	8.0:	17.0:	( ):	23.8:	2.8:
113)	29b	46.6:	9.3:	12.3:	13.0:	11.7:	3.7:	15.8:	0.3:	57.5:	2.4:	28.6:	0.3:	( ):	( ):
114)		33.4:	7.4:	10.8:	11.3:	8.3:	3.1:	24.2:	5.4:	59.7:	13.3:	20.2:	7.0:	( ):	( ):

Table 24.-- Continued

131	35a	49.6	45.3	31.0	28.1	25.4	8.1	20.5	5.1	58.5	19.0	45.1	8.2	15.3	0.5
132		48.5	43.2	32.6	32.4	22.4	7.0	24.7	5.7	59.0	10.7	46.2	( )	26.5	( )
133		45.7	45.8	32.1	30.5	22.2	6.8	26.7	3.9	55.2	11.7	47.8	11.4	23.7	2.3
134		50.6	41.6	31.0	33.5	13.9	11.0	31.5	5.7	55.0	19.8	55.5	14.4	23.6	0.3
147	49a	32.7	12.6	22.3	6.1	24.7	2.0	26.6	0.1	29.3	( )	37.9	8.8	40.2	1.6
149		33.5	8.7	18.2	8.5	18.5	1.3	22.6	0.1	21.3	( )	33.4	0.5	( )	( )
151	38a	( )	( )	23.1	( )	21.7	4.1	19.1	2.8	60.7	21.7	40.8	9.3	( )	( )
152		( )	46.2	22.9	18.6	21.5	4.1	21.7	2.7	71.6	( )	8.8	22.2	( )	( )
153		( )	( )	26.0	20.2	20.4	4.3	22.6	1.9	28.8	23.7	42.7	14.8	( )	( )
154		( )	34.6	27.0	19.5	19.8	6.0	21.6	3.2	73.4	22.6	32.9	( )	( )	( )
155		( )	45.0	27.7	17.9	24.3	6.4	19,8	3.1	73.0	20.9	36.9	( )	( )	( )

Table 25.-- Nitrogen, potash, and phosphoric acid content of total crops of oats and buckwheat grown in succession in duplicate pots.

(a = surface soil; b = subsoil.)

Pot	Soil No		1896		1897		1898		1899		1900		1901		1902	
			Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat	Oats	Buckwheat
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
29	34a	(N	1.14	1.97	1.44	1.97	1.33	( )	1.41	( )	2.06	( )	1.62	1.93	1.68	3.00
		(K_2O	2.69	2.96	2.42	2.32	2.12	1.91	1.81	1.42	2.58	( )	1.12	1.16	1.28	1.41
		(P_2O_5	.53	.35	.77	.34	.67	.18	.51	.30	.52	( )	.44	.78	.44	.82
62	34a	(N	1.30	1.71	1.40	1.85	1.42	2.66	( )	( )	1.87	3.60	1.35	( )	1.20	( )
		(K_2O	3.01	2.54	2.42	2.06	2.22	2.64	1.91	2.51	2.67	( )	2.16	( )	3.04	( )
		(P_2O_5	.71	.33	.89	.44	.62	.43	.46	.25	.43	( )	.27	( )	.48	( )
92	34a	(N	1.10	1.58	1.31	2.15	1.37	2.38	( )	( )	2.00	3.25	1.50	( )	( )	( )
		(K_2O	2.77	2.37	2.54	2.38	1.52	2.59	1.75	( )	2.25	( )	.68	( )	( )	( )
		(P_2O_5	.61	.37	.73	.36	.55	.34	.46	( )	.40	( )	.44	( )	( )	( )
123	34a	(N	1.20	1.82	.91	1.83	1.10	1.97	( )	( )	2.03	3.56	1.97	( )	1.76	3.60
		(K_2O	3.01	2.72	2.65	1.84	1.59	1.88	1.33	1.75	2.02	( )	1.27	( )	1.21	.94
		(P_2O_5	.72	.41	.54	.43	.47	.18	.50	.24	.33	( )	.42	( )	.53	.80
35	3b	(N	1.61	2.08	1.52	2.05	1.96	2.30	1.75	( )	1.77	2.25	1.02	1.48	1.10	2.53
		(K_2O	2.53	2.49	3.03	2.32	2.99	2.42	3.23	2.64	3.35	1.82	3.21	1.99	2.53	2.79
		(P_2O_5	.38	.31	.29	.29	.25	.21	.41	.18	.48	.53	.41	.89	.97	1.36
37	3b	(N	1.52	1.75	1.53	2.01	1.69	2.02	( )	( )	1.65	1.90	.83	1.66	1.10	2.60
		(K_2O	2.49	2.53	3.33	1.65	2.59	2.13	3.48	2.75	3.35	2.24	3.16	2.80	2.42	2.59
		(P_2O_5	.35	.23	.26	.25	.23	.07	.15	.26	.55	.48	1.14	1.14	1.86	1.25

Table 25.-- Continued

		(N	1.56	1.69	1.61	1.85	2.10	2.14	( )	( )	2.06	1.95	1.27	1.88	( )	( )
41:	6b	(K_2O	2.21	3.54	3.50	3.20	3.64	3.35	3.13	3.27	3.70	3.23	3.49	1.83	( )	( )
		(P_2O_5	.25	.23	.34	.26	.29	.21	.38	.25	.31	.67	.41	.80	( )	( )
		(N	1.40	1.82	1.51	1.94	1.91	2.20	( )	( )	1.95	2.06	.92	1.99	( )	( )
43:	6b	(K_2O	2.72	2.52	3.20	2.07	3.33	2.21	3.76	( )	3.54	2.51	3.25	1.98	( )	( )
		(P_2O_5	.36	.29	.38	.23	.17	.21	.34	( )	.38	.57	.85	.79	( )	( )
		(N	1.23	1.34	1.13	1.62	1.34	2.07	1.00	( )	1.94	1.54	1.80	1.90	( )	( )
55:	13b	(K_2O	2.95	1.67	3.05	1.75	3.15	2.10	2.89	1.68	2.69	1.98	3.03	1.35	( )	( )
		(P_2O_5	.30	.26	.40	.25	.31	.18	.33	.38	.25	.52	.50	.50	( )	( )
		(N	1.23	1.70	1.34	1.57	1.21	1.90	( )	( )	1.82	1.57	1.70	1.88	( )	( )
57:	13b	(K_2O	2.93	2.16	3.12	1.69	3.52	2.29	3.28	1.94	2.80	2.07	3.77	1.80	( )	( )
		(P_2O_5	.26	.26	.28	.23	.41	.14	.31	.21	.29	.45	.28	.41	( )	( )
		(N	1.21	2.13	1.30	2.33	1.37	( )	1.62	( )	1.83	2.80	1.06	( )	1.15	( )
65:	18a	(K_2O	1.92	3.12	2.56	3.31	3.06	1.79	2.16	( )	2.74	( )	( )	( )	2.33	( )
		(P_2O_5	.66	.40	.50	.44	.77	.44	.38	( )	.45	( )	( )	( )	.55	( )
		(N	1.25	2.23	1.22	2.18	1.34	( )	( )	( )	1.59	1.92	1.16	( )	1.30	3.30
66:	18a	(K_2O	2.05	3.10	2.19	3.24	2.86	1.80	2.18	( )	2.78	2.20	2.68	( )	1.75	2.50
		(P_2O_5	.68	.45	.48	.44	.43	.41	.22	( )	.43	.65	.44	( )	.48	1.37
		(N	( )	1.34	1.41	1.69	1.83	1.93	2.79	2.23	1.75	2.11	.78	2.16	1.07	( )
70:	20a	(K_2O	( )	2.80	2.76	2.46	3.21	2.52	2.64	2.13	3.30	1.72	2.24	.33	1.71	( )
		(P_2O_5	( )	.50	.68	.58	.78	.44	.51	.35	.63	1.17	.43	.22	.79	( )
		(N	1.61	1.35	1.60	1.54	1.56	2.34	( )	( )	2.05	1.20	.74	2.04	1.15	3.05
72:	20a	(K_2O	2.76	2.96	2.85	2.19	3.19	2.37	2.91	2.06	2.36	2.32	2.56	.45	.63	1.68
		(P_2O_5	.69	.56	.57	.53	.66	.65	.57	.37	.53	1.30	.47	.28	.69	.70

Table 25.-- Continued

		(N	1.02	1.65	1.14	1.72	.97	1.77	( )	( )	1.14	1.40	.76	1.74	1.18	7.57
95	18b	(K_2O	2.36	2.73	1.44	2.82	3.00	2.75	2.47	3.30	2.74	3.13	2.79	2.35	1.72	1.66
		(P_2O_5	.58	.40	.60	.25	.56	.21	.50	.28	.49	.63	.72	1.14	1.23	1.25
		(N	1.14	1.66	1.26	1.38	.85	1.68	( )	( )	1.11	1.47	.83	2.04	.97	( )
97	18b	(K_2O	2.39	2.75	2.60	2.59	3.13	3.06	2.68	1.01	2.72	2.67	2.93	( )	2.00	( )
		(P_2O_5	.56	.48	.75	.41	.75	.35	.47	.28	.58	.65	2.08	( )	1.11	( )
		(N	1.13	( )	1.11	1.26	1.39	1.96	( )	( )	9.68	1.54	.90	1.90	1.41	2.32
98	20b	(K_2O	3.05	( )	3.40	2.33	3.33	2.87	3.03	2.64	3.41	2.29	3.24	.30	2.28	2.34
		(P_2O_5	.54	( )	.72	.43	.68	.33	.33	.35	.39	.61	.39	.17	.37	.28
		(N	( )	1.50	1.36	1.36	1.40	1.93	( )	( )	1.88	1.40	.98	1.57	1.45	2.33
100	20b	(K_2O	( )	2.60	2.92	2.29	2.37	2.47	3.31	2.38	2.16	3.74	3.08	( )	2.20	2.66
		(P_2O_5	( )	.52	.70	.51	.69	.49	.48	.48	.53	.92	.24	( )	.49	.40
		(N	.94	1.61	1.15	1.56	1.21	2.53	1.18	( )	1.12	1.60	.90	( )	( )	( )
113	29b	(K_2O	2.92	1.88	2.66	2.91	5.40	2.20	2.47	1.87	2.32	2.12	2.86	( )	( )	( )
		(P_2O_5	.46	.95	.90	.37	.91	.47	.46	.31	1.09	.74	.99	( )	( )	( )
		(N	.90	1.58	1.16	1.56	1.45	2.56	( )	( )	1.19	1.48	.90	1.79	( )	( )
114	29b	(K_2O	2.90	2.77	2.62	2.58	2.98	2.20	2.15	2.09	2.06	2.48	3.52	.64	( )	( )
		(P_2O_5	.71	1.02	1.11	.86	.93	.61	.50	.59	1.11	1.42	2.09	1.19	( )	( )
		(N	1.30	1.51	1.57	2.34	1.90	3.80	1.94	2.61	( )	1.74	1.08	2.24	1.16	( )
131	35a	(K_2O	2.16	1.95	1.53	1.37	1.18	1.12	1.48	1.52	1.27	2.65	1.06	1.26	1.38	( )
		(P_2O_5	1.23	.85	1.36	.81	.62	.76	.55	.62	.86	1.15	.54	1.10	.61	( )
		(N	1.19	1.36	1.59	1.99	1.33	2.88	( )	( )	2.03	2.13	1.48	2.30	1.13	( )
132	35a	(K_2O	2.17	1.95	1.41	1.48	.91	1.36	1.15	1.39	1.01	1.76	.94	.79	1.17	( )
		(P_2O_5	1.27	.84	1.16	1.05	.59	.97	.64	.77	.69	1.80	.50	.64	.69	( )

Table 25.-- Continued

	(N	1.18	1.40	1.80	2.12	2.04	2.87	( )	( )	1.92	2.44	1.52	1.93	1.13	1.70
133: 35a	(K_2O	2.68	1.96	1.37	1.60	.97	1.46	1.22	1.36	.61	1.64	1,01	1.18	1.38	.64
	(P_2O_5	1.38	.90	1.44	1.16	.73	1.03	.36	.64	.91	1.49	.52	.99	.34	.86
	(N	1.15	1.43	1.42	1.95	2.42	2.73	1.69	3.00	1.85	2.21	1.54	1.92	1.24	2.77
134: 35a	(K_2O	2.76	1.98	1.95	1.69	1.09	1.56	1.51	1.36	1.29	1.95	.92	1.18	1.43	1.44
	(P_2O_5	1.45	.97	1.57	1.09	.73	1.02	.83	.82	.91	2.65	.53	.95	1.14	1.78
	(N	1.09	1.85	1.49	3.00	1.13	2.14	( )	( )	2.12	( )	1.71	2.21	1.87	3.05
147: 49a	(K_2O	2.93	3.25	2.34	2.37	1.38	1.51	1.13	( )	2.17	( )	.82	.84	.87	.75
	(P_2O_5	.57	.42	.75	.63	.50	.26	.53	( )	.42	( )	.41	.70	.62	.52
	(N	1.12	2.20	1.56	2.00	.93	2.16	( )	( )	2.00	( )	1.92	( )	( )	( )
149: 49a	(K_2O	2.99	3.85	2.24	2.16	1.80	1.40	1.50	( )	2.66	( )	1.04	( )	( )	( )
	(P_2O_5	.51	.36	.78	.29	.46	.20	1.52	( )	.38	( )	.44	( )	( )	( )
	(N	( )	( )	1.18	( )	1.58	2.85	( )	( )	( )	1.87	.96	1.62	( )	( )
151: 36a	(K_2O	( )	( )	3.85	( )	3.98	3.34	3.81	3.17	3.42	2.90	3.02	1.94	( )	( )
	(P_2O_5	( )	( )	.77	( )	.65	.41	.48	.40	.49	1.38	.56	.49	( )	( )
	(N	( )	1.46	1.16	1.94	1.56	3.02	( )	( )	( )	1.93	3.61	1.90	( )	( )
152: 36a	(K_2O	( )	3.07	3.53	3.21	4.17	3.36	3.71	2.95	3.42	7.52	5.21	1.78	( )	( )
	(P_2O_5	( )	.64	.80	.60	.69	.57	.40	.33	.48	2.63	.71	.69	( )	( )
	(N	( )	( )	1.16	1.99	1.41	2.97	( )	( )	( )	2.38	1.07	1.54	( )	( )
153: 36a	(K_2O	( )	( )	3.64	3.45	3.34	3.21	3.20	2.96	3.50	7.37	3.04	1.74	( )	( )
	(P_2O_5	( )	( )	.71	.60	.71	.56	.43	.31	.33	1.89	.56	.53	( )	( )
	(N	( )	1.23	1.22	1.99	1.48	3.14	( )	( )	( )	1.71	.90	2.00	( )	( )
154: 36a	(K_2O	( )	4.05	3.85	3.31	3.68	3.40	3.87	3.59	3.32	2.95	3.10	( )	( )	( )
	(P_2O_5	( )	.46	.71	.14	.79	.68	.41	.34	.56	1.06	.68	( )	( )	( )
	(N	( )	1.21	1.14	2.08	1.36	2.60	( )	( )	1.67	1.87	.86	2.35	( )	( )
155: 36a	(K_2O	( )	3.10	3.46	3.14	3.31	3.25	3.84	3.00	( )	2.75	3.22	( )	( )	( )
	(P_2O_5	( )	.50	.67	.68	.70	.48	.46	.38	( )	1.06	.49	( )	( )	( )

Table 26.-- Parts per million of nitrogen, potash, and phosphoric acid taken from the soil by total crops of oats and buckwheat grown in succession and in duplicate pots.

(a = surface soil; b = subsoil.)

Pot	Soil No	1896		1897		1898		1899		1900		1901		1902	
		Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat	Oats	Buck-wheat
	(N	13	10	10	4	12	( )	12	( )	31	( )	36	11	34	2
29	34a (K_2O	15	15	17	5	19	1	15	( )	38	( )	25	7	26	1
	(P_2O_5	6	2	5	1	5	( )	4	( )	8	( )	10	4	9	( )
	(N	9	11	9	11	9	4	( )	( )	27	( )	25	( )	15	( )
62	34a (K_2O	22	16	15	13	15	4	11	1	39	( )	39	( )	39	( )
	(P_2O_5	5	2	6	3	4	1	3	( )	6	( )	5	( )	6	( )
	(N	11	13	12	12	14	3	( )	( )	35	( )	30	( )	( )	( )
92	34a (K_2O	28	19	22	13	16	3	13	( )	39	( )	14	( )	( )	( )
	(P_2O_5	6	3	6	2	6	( )	3	( )	7	( )	9	( )	( )	( )
	(N	11	14	7	10	10	4	( )	( )	34	( )	26	( )	21	3
123	34a (K_2O	27	20	20	10	14	4	13	1	34	( )	17	( )	15	1
	(P_2O_5	7	3	4	2	4	3	5	( )	6	( )	6	( )	6	1
	(N	6	6	10	6	5	2	5	( )	24	13	34	12	19	7
35	3b (K_2O	9	7	10	7	10	2	10	1	46	10	106	16	43	7
	(P_2O_5	1	1	1	1	1	( )	1	( )	7	3	14	7	16	4
	(N	7	7	3	7	5	2	( )	( )	25	11	22	5	8	1
37	3b (K_2O	12	10	6	6	11	2	10	4	50	13	85	8	17	1
	(P_2O_5	2	1	1	1	1	( )	( )	( )	8	3	31	3	13	1

Table 26.-- Continued

		(N	7:	9:	10:	10:	10:	4:	( ):	( ):	51:	12:	44:	17:	( ):	( ):
41:	6b	(K_2O	10:	13:	22:	12:	18:	4:	13:	2:	91:	14:	120:	16:	( ):	( ):
		(P_2O_5	1:	1:	2:	1:	1:	( ):	2:	( ):	8:	4:	14:	7:	( ):	( ):
		(N	9:	9:	9:	8:	8:	2:	( ):	( ):	49:	9:	30:		( ):	( ):
43:	6b	(K_2O	18:	13:	20:	9:	15:	2:	15:	( ):	90:	11:	104:	3:	( ):	( ):
		(P_2O_5	2:	1:	2:	1:	1:	( ):	1:	( ):	9:	3:	27:	1:	( ):	( ):
		(N	7:	5:	4:	5:	5:	3:	5:	( ):	9:	5:	6:	2:	( ):	( ):
55:	13b	(K_2O	16:	6:	10:	5:	13:	3:	14:	1:	13:	7:	9:	2:	( ):	( ):
		(P_2O_5	2:	1:	1:	1:	1:	( ):	2:	( ):	1:	2:	2:	1:	( ):	( ):
		(N	6:	3:	6:	6:	6:	3:	( ):	( ):	5:	6:	5:	3:	( ):	( ):
57:	13b	(K_2O	15:	4:	13:	6:	17:	3:	14:	1:	8:	8:	10:	3:	( ):	( ):
		(P_2O_5	1:	1:	1:	1:	2:	( ):	2:	( ):	1:	2:	1:	1:	( ):	( ):
		(N	10:	17:	18:	18:	18:	( ):	26:	( ):	60:	( ):	31:	( ):	16:	( ):
65:	18a	(K_2O	15:	25:	36:	26:	41:	1:	35:	( ):	85:	( ):	( ):	( ):	31:	( ):
		(P_2O_5	5:	3:	7:	3:	10:	( ):	6:	( ):	14:	( ):	( ):	( ):	7:	( ):
		(N	12:	17:	17:	12:	17:	( ):	( ):	( ):	66:	1:	40:	( ):	( ):	3:
66:	18a	(K_2O	20:	24:	31:	22:	40:	1:	31:	( ):	93:	1:	93:	( ):	49:	9:
		(P_2O_5	7:	4:	7:	4:	6:	( ):	3:	( ):	13:	( ):	15:	( ):	14:	5:
		(N	( ):	16:	17:	19:	15:	14:	13:	10:	59:	32:	8:	2:	14:	( ):
70:	20a	(K_2O	( ):	32:	32:	28:	26:	19:	12:	9:	111:	26:	22:	( ):	22:	( ):
		(P_2O_5	( ):	6:	8:	7:	6:	3:	2:	2:	21:	18:	4:	( ):	10:	( ):
		(N	16:	14:	17:	22:	12:	20:	( ):	( ):	86:	13:	17:	11:	11:	1:
72:	20a	(K_2O	27:	30:	30:	32:	24:	20:	21	11:	99:	34:	58:	2:	6:	( ):
		(P_2O_5	6:	6:	6:	8:	6:	5:	4:	3:	22:	13:	11:	1:	6:	( ):

Table 26.--- Continued

		(N	3	4	5	5	4	2	( )	( )	12	2	8	5	9	3
95	18b	(K_2O	8	6	6	8	13	2	10	2	27	4	28	7	13	1
		(P_2O_5	2	1	2	1	2	( )	2	( )	5	1	7	3	10	1
		(N	4	6	6	8	4	2	( )	( )	18	7	5	( )	19	( )
97	18b	(K_2O	9	9	12	16	15	4	11	2	44	12	17	( )	39	( )
		(P_2O_5	2	2	3	3	4	( )	2	1	9	3	12	( )	22	( )
		(N	3	( )	2	5	4	3	( )	( )	124	4	12	7	20	1
98	20b	(K_2O	9	( )	7	9	10	4	5	3	44	7	44	1	32	2
		(P_2O_5	2	( )	1	1	2	( )	1	( )	5	2	5	1	5	( )
		(N	( )	6	3	6	2	4	( )	( )	82	6	9	( )	22	4
100	20b	(K_2O	( )	10	6	11	3	6	11	6	94	17	29	( )	33	4
		(P_2O_5	( )	2	2	2	1	1	2	1	23	4	8	( )	7	1
		(N	17	6	6	9	6	3	8	( )	27	2	11	( )	( )	( )
113	29b	(K_2O	53	7	14	16	27	2	16	( )	56	2	34	( )	( )	( )
		(P_2O_5	8	3	5	2	4	1	3	( )	26	1	12	( )	( )	( )
		(N	15	6	6	9	6	4	( )	( )	36	10	9	6	( )	( )
114	29b	(K_2O	49	10	14	15	13	3	26	6	62	17	36	2	( )	( )
		(P_2O_5	12	4	6	5	4	1	6	2	34	10	21	4	( )	( )
		(N	33	32	23	31	23	11	19	7	( )	16	23	9	7	( )
131	35a	(K_2O	51	42	22	18	14	4	14	4	35	24	23	6	9	( )
		(P_2O_5	29	18	20	11	7	3	5	1	24	10	12	4	4	( )
		(N	29	29	26	32	15	10	( )	( )	60	11	34	( )	15	( )
132	35a	(K_2O	52	42	23	24	10	4	14	4	30	9	22	( )	15	( )
		(P_2O_5	31	18	19	17	7	3	8	2	20	9	11	( )	9	( )

Table 26.-- Continued

		(N	27:	32:	29:	32:	23:	10:	( ):	( ):	53:	14:	36:	14:	13:	3:
133:	35a	(K_2O	54:	46:	22:	24:	11:	5:	16:	3:	17:	9:	24:	7:	16:	1:
		(P_2O_5	31:	21:	23:	18:	6:	3:	5:	1:	25:	9:	12:	6:	10:	1:
		(N	28:	29:	23:	34:	16:	14:	26:	8:	49:	21:	41:	13:	14:	3:
134:	35a	(K_2O	67:	40:	32:	30:	7:	8:	23:	4:	34:	19:	25:	8:	16:	2:
		(P_2O_5	35:	19:	26:	19:	5:	5:	13:	2:	24:	25:	14:	7:	13:	2:
		(N	14:	9:	14:	5:	11:	2:	( ):	( ):	24:	( ):	25:	8:	29:	2:
147:	49a	(K_2O	37:	16:	21:	6:	13:	1:	12:	( ):	25:	( ):	12:	3:	14:	( ):
		(P_2O_5	7:	2:	7:	2:	5:	( ):	5:	( ):	5:	( ):	6:	2:	10:	( ):
		(N	14:	7:	11:	7:	7:	1:	( ):	( ):	16:	( ):	24:	( ):	( ):	( ):
149:	49a	(K_2O	38:	13:	16:	7:	13:	1:	13:	( ):	21:	( ):	13:	( ):	( ):	( ):
		(P_2O_5	6:	1:	6:	1:	3:	( ):	4:	( ):	3:	( ):	6:	( ):	( ):	( ):
		(N	( ):	( ):	11:	( ):	14:	6:	( ):	( ):	( ):	16:	16:	6:	( ):	( ):
151:	36a	(K_2O	( ):	( ):	36:	( ):	35:	5:	29:	4:	83:	25:	49:	7:	( ):	( ):
		(P_2O_5	( ):	( ):	7:	( ):	6:	1:	4:	( ):	12:	12:	9:	2:	( ):	( ):
		(N	( ):	26:	10:	14:	13:	5:	( ):	( ):	( ):	1:	12:	16:	( ):	( ):
152:	36a	(K_2O	( ):	54:	31:	23:	34:	5:	31:	3:	93:	2:	17:	15:	( ):	( ):
		(P_2O_5	( ):	11:	7:	4:	6:	1:	3:	( ):	13:	2 :	2:	6:	( ):	( ):
		(N	( ):	( ):	11:	15:	11:	5:	( ):	( ):	( ):	21:	17:	9:	( ):	( ):
153:	36a	(K_2O	( ):	( ):	36:	26:	26:	5:	27:	2:	38:	66:	49:	10:	( ):	( ):
		(P_2O_5	( ):	( ):	7:	4:	6:	1:	4:	( ):	4;	14:	9:	3:	( ):	( ):
		(N	( ):	16:	13:	15:	11:	7:	( ):	( ):	( ):	15:	11	2:	( ):	( ):
154:	36a	(K_2O	( ):	53:	40:	25:	28:	8:	32:	4:	93:	25:	39:	( ):	( ):	( ):
		(P_2O_5	( ):	6:	7:	1:	6:	1:	3:	( ):	16:	9:	9:	( ):	( ):	( ):

Table 26.-- Continued

		(N	( )	21	12	14	13	6	( )	( )	46	13	12	2	( )	( )	( )	( )	( )
155	36a	(K_2O	( )	53	36	21	31	8	29	4	( )	22	45	( )	( )	( )	( )	( )	( )
		(P_2O_5	( )	9	7	5	6	1	3	( )	( )	8	7	( )	( )	( )	( )	( )	( )

Table 27.-- Total crop yields of beans and buckwheat grown in succession and in duplicate pots.
(Cowpeas grown instead of beans in 1901, 1902.)

(a = surface soil; b = subsoil.)

Pot:	Soil No	1896		1897		1898		1899		1900		1901		1902	
		Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Cow-peas	Buck-wheat	Cow-peas	Buck-wheat
		Grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams
30:	(34a	15.5	18.6	9.0	6.5	6.1	0.8	3.9	0.3	1.1	( )	( )	12.5	22.8	( )
124:	(34a	18.3	18.8	15.9	13.2	16.2	4.9	12.2	8.3	0.5	1.0	0.8	1.1	1.0	( )
67:	(18a	10.7	8.6	7.9	16.9	5.9	1.8	3.2	0.5	2.0	2.0	50.3	21.6	204.3	( )
68:	(18a	12.1	14.2	5.7	12.5	4.8	1.1	3.7	0.1	( )	( )	1.5	0.1	1.3	( )
148:	(49a	19.4	15.5	19.1	12.1	10.0	2.4	4.6	0.1	( )	( )	2.3	16.3	56.9	( )
150:	(49a	15.9	13.0	16.1	7.1	7.2	1.0	4.1	0.1	1.3	0.3	0.3	0.7	0.5	( )

Table 28.-- Nitrogen, potash, and phosphoric acid content of total crops of beans and buckwheat grown in succession and in duplicate pots.
(Cowpeas grown instead of beans in 1901, 1902.)

(a = surface soil; b = subsoil.)

Pot	Soil No		1896		1897		1898		1899		1900		1901		1902	
			Beans	Buckwheat	Beans	Buckwheat	Beans	Buckwheat	Beans	Buckwheat	Beans	Buckwheat	Cowpeas	Buckwheat	Cowpeas	Buckwheat
			Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
30	34a	(N	2.65	1.79	2.91	2.39	4.38	( )	( )	( )	( )	4.00	3.50	1.93	2.94	
		(K_2O	2.81	3.09	2.51	3.32	3.30	2.43	2.70	2.53	( )	( )	( )	1.60	2.79	
		(P_2O_5	.56	.36	.58	.45	.70	.38	.67	.44	( )	( )	( )	.76	.35	
124	34a	(N	1.23	1.92	2.29	2.09	3.70	2.14	( )	( )	( )	3.48	3.82	( )	( )	
		(K_2O	2.86	2.79	2.30	2.17	2.03	2.35	2.49	2.64	( )	2.31	( )	( )	( )	
		(P_2O_5	.78	.40	.74	.33	.64	.35	.52	.25	( )	1.26	( )	( )	( )	
67	18a	(N	2.72	2.20	3.52	2.40	4.62	2.74	( )	( )	( )	5.60	3.45	2.07	2.20	
		(K_2O	2.94	3.20	3.82	3.58	2.98	2.60	3.52	( )	2.23	2.05	2.74	( )	.84	
		(P_2O_5	.58	.38	.46	.66	.53	.40	1.00	( )	( )	.89	.65	.98	.30	
68	18a	(N	2.74	1.83	3.60	2.36	( )	( )	( )	( )	( )	( )	4.85	( )	( )	
		(K_2O	2.94	3.11	3.57	3.15	3.16	1.80	3.18	( )	1.64	( )	( )	( )	( )	
		(P_2O_5	.57	.39	.50	.41	.70	.39	1.10	( )	.36	( )	( )	( )	( )	
148	49a	(N	2.43	2.17	2.50	2.16	3.73	2.73	( )	( )	( )	( )	4.06	2.18	2.20	
		(K_2O	3.10	3.06	2.30	2.53	2.77	2.73	2.64	( )	( )	( )	( )	1.61	1.76	
		(P_2O_5	.92	.42	.68	.42	.66	.17	.60	( )	( )	( )	( )	.58	.37	
150	49a	(N	2.71	1.95	2.80	2.27	4.18	2.79	( )	( )	( )	( )	4.68	( )	( )	
		(K_2O	3.45	3.64	2.74	2.97	2.74	.81	2.32	( )	( )	( )	( )	( )	( )	
		(P_2O_5	.88	.40	.67	.28	.66	.10	.64	( )	( )	( )	( )	( )	( )	

Table 29.-- Parts per million of nitrogen, potash, and phosphoric acid taken from the soil by total crops of beans and buckwheat grown in succession and in duplicate pots. (Cowpeas grown instead of beans in 1901, 1902.)

(a = surface soil; b = subsoil.)

Pot	Soil No		1896		1897		1898		1899		1900		1901		1902	
			Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Beans	Buck-wheat	Cow-peas	Buck. wheat	Cow-peas	Buck-wheat
30	34a	(N	16	13	11	7	12	( )	( )	( )	( )	( )	( )	11	29	
		(K_2O	17	22	10	9	9	1	5	( )	( )	( )	( )	( )	28	
		(P_2O_5	3	3	2	1	2	( )	1	( )	( )	( )	( )	( )	4	
124	34a	(N	9	14	14	11	( )	( )	( )	( )	( )	( )	1	( )	( )	
		(K_2O	21	21	15	11	13	5	8	2	( )	( )	( )	( )	( )	
		(P_2O_5	6	3	5	2	4	1	2	( )	( )	( )	( )	( )	( )	
67	18a	(N	14	9	15	22	13	1	( )	( )	( )	1	85	22	220	
		(K_2O	15	13	16	33	9	2	6	( )	2	2	68	( )	84	
		(P_2O_5	3	2	2	6	2	( )	2	( )	( )	1	16	10	30	
68	18a	(N	20	15	14	21	( )	( )	( )	( )	( )	( )	4	( )	( )	
		(K_2O	21	26	14	28	9	1	7	( )	( )	( )	( )	( )	( )	
		(P_2O_5	4	3	2	4	2	( )	2	( )	( )	( )	( )	( )	( )	
148	49a	(N	18	13	21	11	14	3	( )	( )	( )	( )	4	14	49	
		(K_2O	23	18	20	14	11	3	5	( )	( )	( )	( )	10	68	
		(P_2O_5	7	3	6	2	3	( )	1	( )	( )	( )	( )	4	14	
150	49a	(N	16	10	19	7	11	1	( )	( )	( )	( )	( )	12	( )	
		(K_2O	21	18	18	9	7	( )	4	( )	( )	( )	( )	( )	( )	
		(P_2O_5	5	2	5	1	2	( )	1	( )	( )	( )	( )	( )	( )	

Table 30.-- Comparison of the total crop yields of oats grown on virgin soil with the amount of water added to the pots;, water expressed as depth in inches over the surface, one inch equalling 4.1 lbs.

(a = surface soil; b = subsoil.)

Pot No:	Soil No:	1896		1897		1898		1899		1900		1901		1902	
		Oats	Water	Oats	Water	Oats	Water	Oats	Water	Oats	Water	Oats	Water	Oats	Water
		grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams
1	1(a	49.5	22.6	31.0	19.1	26.2	22.1	29.5	26.5	84.6	52.4	41.6	32.7	26.8	27.3
31	1(b	34.7	21.0	18.5	18.1	21.1	20.0	20.7	24.0	73.0	47.1	29.7	27.8	b	b
3	2(a	35.8	19.3	21.2	16.2	22.5	20.5	16.7	19.1	67.7	44.6	43.7	27.8	65.9	33.9
33	2(b	8.5	12.4	6.9	12.7	11.7	19.1	6.4	16.7	2.3	13.7	40.2	25.9	75.5	36.1
5	3(a	29.8	16.2	30.0	17.1	16.8	18.7	17.3	19.1	47.6	39.7	41.3	27.8	67.9	32.7
35	3(b	8.1	11.3	6.3	11.7	5.4	13.7	6.9	12.2	30.1	26.5	72.8	35.1	37.3	33.2
9	4(a	23.9	12.4	18.3	15.2	21.0	18.0	21.2	18.1	56.6	46.1	64.1	32.2	34.8	25.9
38	4(b	12.1	13.0	11.4	13.7	12.8	18.1	4.0	14.7	21.9	22.1	35.2	25.9	b	b
10	5(a	46.0	21.0	42.2	19.6	35.4	23.0	38.8	24.5	71.2	51.0	70.0	35.6	b	b
39	5(b	31.6	7.5	18.9	16.6	22.4	20.6	26.8	24.5	81.1	48.5	49.7	31.7	36.9	29.3
7	6(a	40.2	19.4	37.6	18.6	23.4	19.1	18.6	20.6	81.8	52.4	69.8	34.1	60.9	32.7
41	6(b	9.0	11.9	12.7	13.2	10.0	14.2	8.6	14.7	49.4	32.8	69.0	31.7	b	b
12	7(a	30.8	17.8	19.5	18.0	22.0	23.5	13.8	23.0	1.1	14.7	19.9	21.0	55.5	31.7
44	7(b	6.8	11.9	5.0	13.2	7.3	19.1	4.7	17.6	0.4	13.7	25.5	24.9	b	b
14	8(a	47.2	21.6	23.6	19.1	28.1	23.0	28.7	22.0	40.1	38.2	43.8	31.7	45.5	30.7
46	8(b	12.7	13.4	8.8	13.2	9.0	15.7	6.6	14.7	23.5	25.0	51.6	29.8	b	b
16	9(a	47.8	22.1	26.3	18.1	19.6	20.5	34.3	26.0	64.7	52.4	41.0	28.8	47.3	30.7
48	9(b	12.4	13.6	9.3	12.2	12.7	17.6	13.2	17.6	30.1	26.5	37.3	30.2	58.3	32.7

Table 30.-- Continued

18	10(a	51.1:	21.0:	31.0:	19.4:	32.0:	23.5:	34.9:	27.4:	79.9:	55.4:	29.5:	25.9:	17.4: 27.3:
50	10(b	2.4:	7.0:	9.3:	10.3:	7.7:	13.2:	8.8:	10.2:	( ) :	12.2:	18.3:	21.5:	b :b :
19	11(a	52.1:	22.9:	29.3:	18.6:	12.2:	18.0:	17.2:	17.6:	93.1:	55.4:	52.5:	34.6:	39.2: 32.7:
51	11(b	( ):	11.8:	8.6:	13.2:	6.3:	13.2:	8.8:	10.2:	26.3:	25.5:	35.3:	25.9:	55.3: 34.2:
20	12(a	19.4:	25.4:	23.3:	17.6:	20.1:	22.1:	18.9:	27.0:	73.0:	48.5:	37.0:	34.1:	b :b :
52	12(b	11.8:	12.5:	3.5:	12.2:	2.5:	9.3:	9.5:	13.2:	24.3:	24.0:	18.9:	22.9:	b :b :
22	13(a	45.0:	24.8:	36.9:	17.6:	24.9:	22.0:	25.6:	25.0:	75.5:	47.1:	56.0:	31.2:	36.2: 29.8:
55	13(b	16.7:	12.8:	8.7:	11.7:	11.3:	16.5:	13.8:	19.6:	13.2:	49.0:	8.5:	16.6:	b :b :
25	14(a	28.3:	17.8:	24.4:	17.1:	18.8:	19.1:	12.6:	18.1:	82.4:	45.6:	41.9:	27.8:	61.6: 33.9:
58	14(b	( ):	8.7:	3.4:	10.3:	3.5:	8.7:	7.0:	13.6:	13.3:	19.1:	33.9:	22.9:	b :b :
27	15(a	48.7:	27.0:	28.6:	19.1:	31.8:	24.0:	35.7:	30.9:	78.6:	54.9:	52.2:	30.7:	38.6: 28.3:
60	15(b	6.6:	10.4:	5.1:	12.2:	12.0:	17.6:	3.9:	15.0:	20.6:	25.5:	48.2:	34.1:	42.8: 24.9:
127	16(a	4.4:	10.5:	4.9:	18.6:	6.3:	16.6:	4.0:	12.7:	8.7:	17.2:	47.8:	31.7:	34.9: 36.1:

b Not planted

Table 31.-- Comparison of total crop yields of beans and cowpeas grown on virgin soils with the amount of water added to the pots; water expressed as depth in inches over the surface, one inch equalling 4.1 lbs.

(a = surface soil; b = subsoil.)

Pot No:	Soil No:	1896		1897		1898		1899		1900		1901		1902	
		Beans	Water	Beans	Water	Beans	Water	Beans	Water	Beans	Water	Cow-peas	Water	Cow-peas	Water
		grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams
2	1 (a	34.0	11.3	42.1	15.7	26.9	14.2	27.7	17.1	37.8	22.5	99.8	53.2	164.1	72.2
32	1 (b	35.9	12.4	43.0	15.2	30.7	15.7	28.8	16.7	40.3	23.5	94.2	54.1	b	b
4	2 (a	16.9	9.2	12.2	12.2	9.8	9.8	6.4	9.8	2.1	12.2	.7	12.7	75.7	36.1
34	2 (b	4.9	8.1	3.8	9.3	5.4	9.3	4.1	8.3	1.3	6.3	1.0	10.7	204.1	37.1
6	3 (a	28.2	11.3	24.4	14.2	17.9	11.7	11.2	10.8	3.0	9.3	2.6	14.1	247.8	68.8
36	3 (b	13.5	8.6	12.1	10.8	14.2	10.8	9.9	11.8	2.3	63.7	62.4	44.4	167.0	39.0
11	5 (a	39.7	13.0	43.9	14.7	31.9	15.2	32.4	18.1	68.5	27.5	90.5	49.3	b	b
40	5 (b	21.5	9.7	31.6	14.2	27.1	14.7	20.4	14.7	33.0	19.1	74.9	38.8	131.6	39.5
8	6 (a	30.1	11.9	34.5	15.7	23.7	13.2	16.8	12.2	4.2	10.3	2.3	11.2	289.5	72.2
42	6 (b	12.4	14.0	16.4	15.2	12.8	11.2	8.5	9.8	2.5	63.7	3.1	17.1	b	b
13	7 (a	21.0	10.8	14.2	12.7	11.7	12.7	6.0	11.7	1.0	11.1	2.4	18.5	175.4	61.5
45	7 (b	9.5	8.6	19.4	12.2	9.4	12.2	11.3	13.2	1.2	73.5	38.8	33.7	b	b
15	8 (a	35.5	13.0	29.6	15.2	23.6	13.7	25.4	15.2	32.0	19.6	54.2	46.3	123.3	67.8
47	8 (b	17.0	10.2	19.4	12.7	18.0	12.0	17.7	14.2	14.3	12.5	77.6	47.8	b	b
17	9 (a	29.8	10.8	31.8	14.7	20.6	13.2	12.7	12.2	3.0	10.3	27.8	24.4	207.7	68.3
49	9 (b	14.0	10.2	8.7	10.3	9.9	10.8	7.0	9.3	1.0	63.7	1.8	11.2	140.7	25.4
21	12 (a	21.1	9.7	30.4	12.7	25.9	13.2	23.1	15.2	33.2	20.1	92.9	53.7	b	b
--	12 (b	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )

Table 31.-- Continued

23	13(a	29.7	10.3	28.7	15.7	31.6	16.5	20.9	15.7	26.9	21.6	53.0	41.0	99.6	61.0
56	13(b	15.2	9.2	16.4	9.8	21.6	11.7	20.5	13.2	11.3	11.3	9.0	15.1	b	b
26	14(a	27.3	11.3	29.2	15.2	19.3	12.2	10.0	10.3	7.9	10.8	.9	10.7	130.6	43.9
59	14(b	10.5	9.6	6.9	9.8	6.6	7.8	6.1	8.8	1.3	49.0	45.5	21.0	b	b
28	15(a	33.1	11.9	34.0	15.2	42.0	16.1	33.4	10.3	24.3	18.7	68.7	47.3	151.9	70.7
61	15(b	17.7	8.7	29.0	13.2	15.5	13.7	14.4	12.2	3.0	68.6	100.4	52.2	205.1	72.0
128	16(a	14.1	8.8	15.6	12.7	20.7	12.7	13.8	19.6	2.1	34.3	59.5	44.4	93.5	66.3

b Discontinued

Table 32.-- Comparison of total crop yields of oats grown on cultivated soils with amount of water added to the pots; water expressed as depth in inches over the surface, one inch equalling 4.1 lbs.

(a = surface soil;, b = subsoil.)

Pot	Soil No	1896		1897		1898		1899		1900		1901		1902	
		Oats	Water	Oats	Water	Oats	Water	Oats	Water	Oats	Water	Oats	Water	Oats	Water
		grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams
63	17 (a	47.7	19.1	19.3	16.2	15.7	18.1	19.8	22.0	73.5	48.5	18.2	25.9	13.9	24.9
93	17 (b	28.1	17.6	7.9	12.2	8.2	15.2	7.9	15.2	51.8	38.7	10.5	21.5	( )	( )
65	18 (a	14.5	14.3	25.2	16.6	24.0	22.1	29.4	25.5	56.3	37.0	52.4	30.7	24.4	24.4
95	18 (b	7.8	10.8	9.9	12.7	10.1	15.2	10.0	16.2	24.5	25.5	24.3	23.9	18.8	25.9
69	19 (a	30.1	14.7	20.9	16.2	24.1	20.6	19.2	22.0	76.5	47.5	43.8	31.2	49.1	33.9
101	19 (b	9.5	11.5	8.5	13.2	13.0	17.6	9.5	18.6	42.7	33.8	59.2	34.1	41.2	30.7
70	20 (a	( )	13.2	23.0	16.2	16.0	17.1	8.9	17.1	66.3	50.5	59.3	36.1	25.7	27.3
98	20 (b	7.1	9.7	4.2	10.8	6.3	13.2	3.8	13.7	27.6	25.0	29.4	25.9	29.8	25.9
73	21 (a	27.1	14.5	23.2	17.6	22.6	20.6	16.4	22.0	49.1	35.8	52.9	34.1	51.1	29.3
102	21 (b	11.1	11.1	6.9	13.7	8.9	15.7	2.9	13.7	31.6	28.4	42.2	29.8	( )	( )
74	22 (a	41.1	18.0	34.8	17.6	30.7	21.5	18.4	23.5	67.5	44.1	79.9	37.1	55.1	32.2
103	22 (b	10.7	12.0	13.3	13.2	7.8	12.7	15.1	16.6	55.5	37.7	31.8	26.8	( )	( )
76	23 (a	61.4	24.5	49.1	20.1	43.6	24.5	48.6	28.9	88.8	50.0	83.1	39.5	( )	( )
104	23 (b	32.5	16.0	16.2	16.7	5.4	11.7	9.0	16.2	68.9	39.8	45.4	24.4	39.4	25.9
106	24 (a	31.0	19.0	13.7	14.7	12.2	18.1	10.9	18.1	5.2	14.3	39.6	28.3	22.7	26.8
78	24 (b	1.9	9.7	2.9	12.7	6.1	22.5	2.7	17.1	1.6	12.7	27.1	25.9	( )	( )
80	25 (a	48.8	21.8	34.4	19.1	33.1	23.0	27.8	20.1	38.5	28.4	63.2	35.1	48.2	30.2
108	25 (b	11.7	12.0	6.6	12.7	9.8	16.2	6.3	16.2	28.1	24.6	43.6	30.2	( )	( )

Table 32.-- Continued

82:	26(a	63.5	23.6	41.0	19.1	34.9	24.0	32.6	22.5	76.1	48.5	43.0	31.2	( ): ( ):
109:	26(b	14.3	13.5	8.0	12.7	9.7	16.6	12.4	16.6	36.5	27.8	25.6	25.4	( ): ( ):
84:	27(a	36.9	17.8	22.3	17.1	22.1	20.6	14.1	19.1	75.7	48.0	26.0	23.4	12.5: 24.9:
111:	27(b	8.9	11.7	5.5	10.8	9.9	16.6	8.2	15.2	21.6	19.9	16.9	22.4	( ): ( ):
85:	28(a	21.1	16.8	20.3	16.6	17.0	16.2	19.2	19.1	85.8	51.5	60.3	35.1	48.3: 30.2:
112:	28(b	6.5	10.8	4.1	11.3	3.3	11.3	1.6	11.8	28.7	24.5	35.2	25.9	( ): ( ):
86:	29(a	65.3	22.0	32.7	20.1	32.5	24.0	40.3	34.8	84.0	52.0	57.1	36.1	( ): ( ):
113:	29(b	46.6	20.7	12.5	13.2	11.7	16.6	15.8	18.6	57.5	39.3	28.6	28.3	( ): ( ):
87:	30(a	44.0	17.3	24.8	17.6	22.3	22.5	21.2	19.6	88.1	52.0	40.6	29.8	20.0: 26.8:
118:	30(b	16.3	11.2	23.6	15.2	22.1	20.0	10.4	17.7	19.6	22.1	69.8	35.6	( ): ( ):
89:	31(a	29.7	17.6	26.3	16.6	16.4	17.1	12.7	14.7	58.7	37.7	40.2	27.3	46.6: 30.2:
120:	31(b	8.9	10.4	3.7	10.8	8.8	12.7	4.9	12.2	23.0	21.8	38.7	24.4	( ): ( ):
90:	32(a	35.1	21.5	29.1	18.6	35.3	24.5	25.1	24.5	85.2	49.0	36.5	30.7	37.1: 30.2:
121:	32(b	7.4	11.7	5.2	11.7	6.9	14.7	5.4	16.2	32.9	28.9	38.8	30.2	( ): ( ):
129:	33(a	14.3	14.1	8.8	14.2	10.4	15.2	13.2	19.1	50.1	38.7	47.9	31.2	64.6: 33.2:
29:	34a	28.7	16.2	19.2	17.1	22.6	22.0	19.7	17.1	35.7	34.3	53.2	33.2	48.4: 27.8:
131:	35a	49.6	22.2	31.0	19.6	25.4	19.6	20.5	19.6	58.5	41.9	45.1	30.2	13.3: 24.9:
151:	36a	( ):	( ):	23.1	17.1	21.7	21.0	19.1	21.1	60.7	45.6	40.8	29.8	( ): ( ):
156:	37a	( ):	( ):	17.8	13.2	24.5	20.6	30.2	28.4	55.5	42.6	14.0	21.5	34.4: 25.9:
158:	38a	( ):	( ):	34.1	13.2	28.2	22.0	48.9	35.3	74.7	56.9	52.7	32.7	55.0: 32.7:

Table 32.-- Continued

160:	39a	: ( ):	( ):	20.1:	13.2:	24.6:	22.0:	33.1:	28.4:	52.2:	42.6:	30.2:	26.8:	34.9:	27.8:
162:	40a	: ( ):	( ):	39.1:	13.2:	36.8:	23.5:	56.7:	24.0:	104.7:	57.4:	75.8:	31.2:	56.2:	31.2:
164:	41a	: ( ):	( ):	29.6:	14.7:	28.7:	24.5:	38.0:	27.4:	64.3:	51.5:	44.9:	30.7:	48.6:	31.2:
166:	42a	: ( ):	( ):	22.4:	13.7:	35.6:	24.0:	33.1:	30.4:	48.7:	38.7:	32.8:	27.3:	56.5:	34.2:
168:	43a	: ( ):	( ):	38.9:	15.7:	32.6:	23.0:	45.7:	34.3:	105.0:	59.3:	64.1:	34.6:	50.6:	32.7:
170:	44a	: ( ):	( ):	23.4:	12.2:	26.7:	24.0:	31.8:	27.4:	79.0:	49.0:	39.9:	29.3:	25.4:	25.4:

Table 33.-- Comparison of total crop yields of beans and cowpeas grown on cultivated soils with the amounts of water added to the pots;, water expressed as depth in inches over the surface, one inch equalling 4.1 lbs.

(a = surface soil; b = subsoil.)

Pot:	Soil No	1896		1897		1898		1899		1900		1901		1902	
		Beans	Water	Beans	Water	Beans	Water	Beans	Water	Beans	Water	Cow-peas	Water	Cow-peas	Water
		grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams
64:	17(a	26.1	10.5	41.0	15.7	23.5	13.7	19.8	16.2	44.1	24.5	108.9	53.7	183.4	70.7
94:	17(b	24.2	9.8	26.5	13.2	19.7	12.7	19.2	13.2	25.0	17.2	97.2	48.8	( )	( )
67:	18(a	10.7	8.5	7.9	8.8	5.9	9.3	3.2	7.3	2.0	80.8	50.3	29.3	204.3	71.7
96:	18(b	7.4	7.2	7.9	9.7	8.5	11.3	6.8	8.8	3.0	12.3	74.4	39.5	166.7	35.1
71:	20(a	27.2	11.2	32.7	14.7	25.4	13.2	27.5	16.2	65.6	29.4	95.5	48.8	64.7	47.8
99:	20(b	16.0	9.3	15.3	10.3	16.9	11.3	16.2	14.2	17.1	17.2	62.7	45.4	49.2	30.7
75:	22(a	26.3	10.5	41.1	14.2	33.9	15.7	25.7	16.2	51.0	24.3	84.0	49.3	134.3	64.9
--:	22(b	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
77:	23(a	49.9	14.1	43.4	15.7	38.8	16.6	28.2	18.1	63.1	27.9	87.3	48.8	( )	( )
105:	23(b	26.6	13.6	24.6	13.7	14.9	18.1	10.0	10.8	( )	19.0	( )	15.1	235.6	38.0
79:	24(a	8.9	8.1	13.8	10.8	12.1	12.7	10.0	13.7	( )	68.6	46.4	39.0	54.2	48.3
107:	24(b	20.3	9.5	12.4	13.2	11.2	11.3	7.8	11.3	( )	11.1	6.8	15.1	( )	( )
81:	25(a	31.0	10.5	31.9	14.2	32.0	15.7	20.8	13.7	13.4	12.7	60.1	47.3	126.7	67.8
--:	25(b	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
83:	26(a	45.8	12.0	46.6	15.7	38.5	17.1	31.8	16.1	76.0	32.4	103.5	50.7	( )	( )
110:	26(b	20.6	10.1	11.4	9.3	10.4	11.3	8.9	10.8	( )	19.0	( )	16.6	( )	( )
88:	30(a	29.4	10.9	27.0	13.2	16.4	14.7	19.2	13.7	41.0	21.6	114.0	50.7	115.6	64.9
119:	30(b	18.6	8.5	20.3	11.7	24.4	12.2	14.1	11.8	14.0	12.3	64.6	34.1	( )	( )

Table 33.-- Continued

91:	32(a	: 33.5:	12.0:	39.7:	14.2:	36.5:	13.7:	29.0:	15.7:	58.3:	27.5:	116.2:	51.7:	160.3:	74.6:
122:	32(b	: 16.7:	7.6:	25.4:	12.2:	14.5:	11.2:	10.7:	11.3:	9.3:	11.3:	89.7:	51.7:	( ):	( ):
130:	33(a	: 15.3:	9.6:	12.4:	10.3:	13.3:	10.8:	7.5:	14.7:	7.9:	93.2:	70.4:	42.4:	( ):	( ):
30:	34a	: 15.5:	8.6:	9.0:	9.8:	6.1:	8.8:	3.9:	10.8:	( ):	58.8:	( ):	12.7:	22.8:	27.3:
157:	37a	: ( ):	( ):	24.2:	13.2:	24.7:	15.2:	21.9:	15.7:	8.4:	12.3:	6.0:	22.9:	156.3:	58.0:
159:	38a	: ( ):	( ):	40.7:	13.7:	31.7:	17.1:	31.6:	18.6:	8.8:	11.8:	73.4:	44.9:	102.5:	67.8:
161:	39a	: ( ):	( ):	23.9:	13.1:	25.7:	15.7:	26.7:	18.1:	3.7:	73.5:	7.0:	22.0:	184.6:	64.4:
163:	40a	: ( ):	( ):	41.2:	16.1:	28.7:	17.1:	40.8:	20.0:	20.8:	15.7:	104.6:	51.7:	117.6:	73.2:
165:	41a	: ( ):	( ):	38.3:	13.2:	28.6:	16.1:	37.3:	19.1:	4.7:	73.5:	59.2:	38.5:	108.8:	66.3:
167:	42a	: ( ):	( ):	22.5:	13.2:	27.7:	17.1:	25.9:	16.7:	10.3:	12.8:	8.9:	18.5:	159.9:	70.7:
169:	43a	: ( ):	( ):	40.7:	14.7:	40.6:	17.6:	39.3:	18.1:	20.3:	16.7:	( ):	52.7:	184.0:	80.0:
171:	44a	: ( ):	( ):	24.3:	14.2:	29.4:	15.2:	20.7:	16.2:	7.3:	12.3:	15.4:	20.5:	( ):	73.2:

Table 34.-- Comparison of total crop yields of oats grown on Florida muck soils with the amount of water added to the pots; water expressed as depth in inches over the surface, one inch equalling 4.1 lbs.

(a = surface soil; b = subsoil.)

Pot	Soil No	1896		1897		1898		1899		1900		1901		1902	
		Oats	Water	Oats	Water	Oats	Water	Oats	Water	Oats	Water	Oats	Water	Oats	Water
		grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams	grams
135	)	25.1	19.4	15.1	18.1	7.0	15.7	11.3	17.6	21.7	28.9	11.7	19.5	2.0	11.2
136	)	43.4	19.9	19.9	18.1	6.8	15.7	13.0	13.7	28.6	30.9	35.9	27.3	36.2	26.3
137	)45a	31.2	19.9	20.4	18.1	11.1	16.6	14.2	13.7	26.4	30.9	27.8	24.9	21.5	22.9
138	)	32.9	19.9	20.8	18.1	11.3	16.6	14.6	14.5	25.0	29.4	30.9	25.4	20.2	22.0
139	)	17.6	18.8	13.5	18.1	8.0	15.7	25.4	15.7	17.0	26.0	10.2	18.5	15.7	19.0
140	)	42.3	19.9	24.8	18.1	16.3	17.1	22.0	14.7	28.0	28.9	46.2	32.7	32.6	25.4
141	)46a	46.4	19.9	27.9	18.1	13.8	15.7	23.0	14.2	23.6	28.4	19.3	21.5	50.0	31.2
142	)	48.4	19.9	25.2	18.1	10.6	15.7	19.9	13.7	23.6	28.4	18.7	20.0	47.2	31.7
143	)47a	36.1	( )	23.7	18.1	11.6	15.7	17.9	13.7	26.9	28.9	45.0	30.7	45.2	30.2
144	)	35.2	19.9	23.6	18.1	12.7	15.7	16.4	14.2	31.4	28.9	37.6	30.7	34.1	31.2
145	)48a	34.4	19.9	22.1	18.1	14.8	17.1	15.1	13.7	23.4	29.4	19.3	23.4	16.6	24.9
146	)	29.9	20.5	18.2	18.1	12.5	17.1	9.1	13.7	26.2	28.9	20.8	23.9	17.0	22.9

Table 35 a.-- Evaporation in weekly periods during the growth of the crops.

(a = surface soil; b = subsoil.)

Pot No.	Soil No.	Year	Crop	Weight	Number of weeks after planting											
					3	4	5	6	7	8	9	10	11	12	13	14	15
				grams	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	1a	1899	Oats	29	3	5	6	14	15	6	12	9	11	6			
1	1a	1900	do	84	7	6	12	25	18	16	21	27	19	27	14	8	
7	6a	1899	do	18	0	4	3	9	12	6	9	8	6	6			
7	6a	1900	do	82	7	4	10	22	15	18	23	31	20	26	13	9	
14	8a	1899	do	29	2	3	5	10	16	6	8	9	9	7			
14	8a	1900	do	40	7	4	10	21	17	14	18	13	8	14	6	6	
19	11a	1899	do	17	2	3	4	6	9	5	6	7	6	4			
19	11a	1900	do	93	7	6	14	24	23	18	23	24	20	29	13	11	
25	14a	1899	do	12	2	3	6	6	13	3	6	6	4	4			
25	14a	1900	do	82	7	4	11	20	17	14	11	27	17	23	12	9	
2	1a	1899	Beans	28	3	6	8	13	17	3							
2	1a	1900	do	38	8	5	10	11	9	10	12	9					
11	5a	1899	do	32	5	8	6	14	18	3							
11	5a	1900	do	68	8	5	10	19	16	11	16	7					
15	8a	1899	do	25	3	6	6	10	13	3							
15	8a	1900	do,	32	4	2	5	8	8	7	11	13	3				

Table 35 a.-- Continued

23	13a	1899	do	21	4:	5:	5:	12:	12:	2:	:	:	:	:	:	:	:
23	13a	1900	do	27	6:	6:	4:	6:	7:	7:	11:	13:	8:	:	:	:	:
28	15a	1899	do	33	4:	6:	8:	15:	17:	3:	:	:	:	:	:	:	:
28	15a	1900	do	24	4:	7:	8:	6:	6:	9:	8:	:	:	:	:	:	:
135	45a	1899	Oats	11	3:	4:	6:	9:	10:	4:	8:	7:	7:	5:	:	:	:
135	45a	1900	do	22	11:	4:	5:	7:	6:	5:	10:	12:	14:	14:	6:	8:	5:
139	46a	1899	do	25	4:	4:	6:	10:	13:	9:	9:	10:	8:	6:	:	:	:
139	46a	1900	do	17	4:	3:	5:	7:	7:	7:	9:	11:	11:	11:	5:	6:	5:
174	34a	1899	Blank		2:	3:	3:	4:	5:	4:	2:	4:	3:	3:	:	:	:
174	34a	1900	do		6:	2:	2:	3:	3:	2:	3:	3:	4:	3:	2:	3:	:
175	34a	1899	do		1:	1:	2:	4:	5:	2:	3:	3:	4:	3:	:	:	:
175	34a	1900	do		4:	2:	3:	2:	5:	2:	2:	4:	4:	3:	3:	3:	:
176	34a	1899	do		2:	1:	2:	5:	5:	2:	4:	4:	2:	4:	:	:	:
176	34a	1900	do		4:	1:	1:	0:	3:	3:	1:	3:	5:	3:	3:	2:	:
177	34a	1899	do		1:	0:	3:	3:	6:	3:	4:	4:	2:	4:	:	:	:
177	34a	1900	do		3:	2:	2:	1:	3:	4:	1:	3:	5:	3:	4:	2:	:

Table 35 b.— Climate during growth of the two crops for each year of the experiment.

Climatic data	1896		1897		1898		1899		1900		1901		1902	
	Crop		Crop		Crop		Crop		Crop		Crop		Crop	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Planting date	Mar.31	Jul.15	Apr. 6	Jul.27	Mar.30	Aug. 2	Apr.14	Aug. 2	Apr.28	Aug.17	Apr.11	Aug.28	Apr.14	Aug.11
Harvesting date	Jul. 1	Sep.18	Jul.10	Sep.28	Jul. 2	Oct.14	Jul.19	Oct.19	Aug. 8	Nov. 7	Aug. 1	Nov.11	Jul.25	Oct.10
Pressure-- inches														
Mean actual	29.94	29.93	29.91	29.91	29.92	29.96	29.94	29.94	29.89	29.98	29.85	30.02	29.89	29.91
Absolute range	.95	.82	1.15	.71	.88	.74	.67	.81	.97	.74	.95	.93	.98	.81
Temperature- -degrees F														
Mean	65.60	74.20	66.20	71.80	63.00	71.80	68.80	66.60	71.70	69.10	68.10	59.50	69.00	65.80
Highest	94.00	98.00	93.00	97.00	97.00	95.00	97.00	96.00	99.00	97.00	102.00	92.00	99.00	91.00
Lowest	28.00	50.00	29.00	42.00	26.00	48.00	27.00	33.00	38.00	35.00	37.00	26.00	33.00	43.00
Mean maximum	75.00	83.80	76.20	82.30	72.90	81.10	79.60	76.20	82.70	77.90	77.80	70.50	79.80	75.40
Mean minimum	56.10	64.60	56.20	61.40	53.20	62.50	58.00	57.00	60.70	60.30	58.40	48.50	58.00	57.50
Absolute range	66.00	48.00	64.00	55.00	71.00	47.00	70.00	63.00	61.00	62.00	65.00	66.00	66.00	48.00
Mean range	18.90	19.20	20.00	20.90	19.70	18.60	21.60	19.20	22.00	17.60	19.40	22.00	21.80	17.90
Humidity-														
Mean absolute grams per cubic foot	4.67	6.46	4.88	6.37	4.24	6.31	5.21	5.57	5.46	5.80	5.44	4.09	5.03	5.38
Mean relative per cent	71.20	74.70	70.40	77.70	71.00	79.90	69.70	82.90	66.40	80.10	74.90	77.20	66.70	78.40
Number days clear	32	35	44	32	36	33	47	35	56	38	50	37	44	26
Partly cloudy	20	13	24	21	38	28	31	25	23	16	23	24	48	27
Cloudy	30	17	27	10	20	12	18	18	23	28	40	15	11	8
Average cloudiness	5.2	4.2	4.5	3.7	4.8	4.4	4.0	4.4	3.9	4.8	5.0	4.1	4.3	4.1
Wind, average daily, miles	150	130	163	130	165	127	145	124	142	123	144	131	161	120

Table 36.-- Mechanical somposition of virgin soils.

(a = surface soil; b = subsoil.)

Soil No		Greater than 0.25 mm	Greater than 0.10 mm	Greater than 0.05 mm	Greater than 0.025 mm	Greater than 0.012 mm	Greater than 0.006 mm	Will not float 18 hours	Will float 18 hours	Loss on ignition
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
1	a	10	17	18	12	12	5	8	11	8
	b	7	20	24	11	10	5	7	11	5
2	a	2	4	17	34	11	6	12	8	2
	b	2	4	12	38	11	7	11	12	3
3	a									
	b									
4	a	3	4	9	26	11	9	18	9	9
	b	4	1	8	24	12	9	21	15	6
5	a	9	14	14	24	8	4	10	7	11
	b	14	20	16	16	6	4	8	7	8
6	a	2	4	26	35	7	3	7	9	9
	b	2	3	22	33	7	3	10	13	7
7	a	3	9	52	20	3	2	2	2	6
	b	3	12	59	14	3	3	2	2	2
8	a	20	37	15	7	7	3	2	1	6
	b	18	37	16	7	7	3	3	6	10

Table 36.-- Continued

9	(a	2:	4:	16:	37:	9:	5:	11:	9:	7:
	(b	2:	2:	22:	33:	8:	5:	10:	14:	4:
10	(a	2:	5:	31:	20:	15:	4:	6:	9:	7:
	(b	1:	3:	33:	25:	14:	5:	4:	7:	8:
11	(a	21:	20:	15:	15:	9:	3:	8:	1:	7:
	(b	21:	24:	15:	13:	6:	3:	10:	5:	2:
12	(a									
	(b									
13	(a	14:	30:	16:	14:	9:	3:	2:	5:	7:
	(b	10:	22::	19:	13:	10:	5:	5:	10:	6:
14	(a	1:	32:	33:	11:	10:	3:	2:	5:	3:
	(b	:	:	:	:	:	:	:	:	:
15	(a	4:	10:	12:	25:	16:	9:	10:	7:	5:
	(	3:	9:	16:	23:	18:	8:	11:	9:	2:
16	(a	1:	4:	10:	24:	8:	7:	17:	23:	5:
	(b									

Table 37.-- Mechanical composition of cultivated soils.

(a = surface soil; b = subsoil.)

Soil No		Greater than 0.25 mm	Greater than 0.10 mm	Greater than 0.05 mm	Greater than 0.025 mm	Greater than 0.012 mm	Greater than 0.006 mm	Will not float 18 hours	Will float 18 hours	Loss on ignition
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
17	(a	6:	14:	20:	11:	15:	5:	8:	14:	7:
	(b	10:	17:	19:	11:	12:	5:	8:	10:	8:
18	(a	1:	13:	18:	15:	8:	4:	18:	13:	9:
	(b	0:	9:	41:	17:	6:	4:	8:	10:	4:
19	(a	2:	5:	12:	34:	19:	9:	8:	7:	4:
	(b	2:	5:	12:	33:	20:	8:	7:	9:	3:
20	(a	2:	6:	7:	25:	10:	6:	15:	15:	12:
	(b	1:	3:	7:	26:	9:	7:	18:	2:	5:
21	(a	6:	5:	9:	22:	27:	6:	8:	7:	7:
	(b	3:	2:	6:	30:	15:	5:	19:	13:	6:
22	(a	13:	23:	11:	14:	12:	3:	4:	7:	12:
	(b	7:	14:	8:	16:	16:	6:	9:	2:	9:
23	(a	1:	4:	28:	32:	7:	3:	8:	8:	8:
	(b	1:	2:	19:	32:	7:	4:	12:	16:	7:
24	(a	3:	7:	49:	21:	9:	2:	1:	1:	6:
	(b	2:	6:	55:	27:	4:	1:	1:	1:	3:
25	(a	12:	36:	21:	7:	8:	4:	2:	2:	5:
	(b	12:	35:	22:	8:	10:	4:	3:	4:	2:

Table 37.-- Continued

26	(a	3:	4:	13:	38:	19:	4:	6:	6:	6:
	(b	:	:	:	:	:	:	:	:	:
27	(a	1:	2:	30:	20:	16:	4:	8:	12:	6:
	(b	1/2:	18:	33:	25:	13:	4:	5:	8:	9:
28	(a	18:	23:	16:	13:	6:	3:	9:	5:	5:
	(b	32:	22:	11:	10:	4:	4:	7:	6:	3:
29	(a	:								
	(b	:								
30	(a	14:	31:	22:	11:	8:	2:	1:	4:	6:
	(b	12:	26:	22:	12:	10:	4:	2:	5:	7:
31	(a	1:	27:	42:	8:	7:	5:	3:	5:	2:
	(b	1:	16:	28:	8:	6:	3:	6:	25:	5:
32	(a	2:	4:	12:	27:	20:	9:	11:	7:	5:
	(b	4:	5:	13:	23:	18:	9:	12:	11:	3:

Table 38.-- Results of soil analyses using 10 grams of sample in 100 cc of hydrochloric acid(1.115 sp. gr.) at 100° C. and varying the time of digestion.

(a = surface soil; b = subsoil.)

Soil No:	No.hours digested:	Insoluble residue:	Al_2O_3 :	Fe_2O_3 :	Mn_2O_3 :	CaO :	MgO :	SO_3 :	P_2O_5 :	(NaCl (KCS :
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
3a	1	83.43	3.34	3.00	0.08	0.50	0.49	0.07	0.11	0.46
3a	5	80.31	4.37	3.24	0.15	0.62	0.64	0.06	0.11	0.70
3a	10	80.26	5.15	3.32	0.20	0.62	0.68	0.06	0.11	0.97
3a	20	79.55	5.74	3.32	( )	0.64	0.67	0.06	0.11	1.13
3b	1	83.72	4.10	3.64	0.08	0.45	0.62	0.04	0.06	0.47
3b	5	80.30	5.84	3.80	0.23	0.55	0.85	0.05	0.07	0.70
3b	10	79.46	6.77	4.16	0.20	0.55	0.85	0.05	0.07	0.92
3b	20	78.13	7.06	4.16	0.20	0.59	0.85	0.04	0.07	1.20
18a	1	77.23	6.20	4.98	0.08	0.51	1.25	0.06	0.14	0.71
18a	5	72.50	8.45	5.06	0.13	0.83	1.53	0.08	0.14	0.78
18a	10	72.12	9.15	5.50	0.13	0.90	1.61	0.08	0.15	1.06
18a	20	71.33	9.61	5.54	0.13	1.05	1.61	0.08	0.13	1.21
18b	1	85.53	4.46	3.60	0.08	0.52	1.18	0.04	0.06	0.64
18b	5	( )	6.60	3.84	0.08	0.86	1.38	0.04	0.06	0.70
18b	10	81.24	6.50	4.12	0.08	0.97	1.52	0.04	0.06	1.04
18b	20	80.97	6.94	4.14	0.07	1.12	1.53	0.04	0.05	1.12
20a	1	77.72	4.14	3.00	0.08	1.30	0.75	0.09	0.18	0.38
20a	5	76.06	5.08	3.08	0.08	1.40	1.03	0.11	0.18	0.70
20a	10	75.14	6.26	3.32	0.10	1.43	1.03	0.11	0.18	0.87
20a	20	74.14	6.52	3.36	0.10	1.46	1.03	0.10	0.18	0.91

Table 38.-- Continued

20b	1	84.32	4.37	3.44	0.10	0.89	0.90	0.03	0.11	0.47
20b	5	81.65	4.91	3.56	0.21	0.94	1.00	0.04	0.11	0.67
20b	10	81.19	6.36	3.76	0.19	0.98	1.14	0.04	0.11	1.00
20b	20	79.95	6.72	3.80	0.19	1.00	1.13	0.04	0.12	1.27

Table 39.-- Results of analyses of virgin soils digesting 10 grams of soil in hydrochloric acid (1.115 sp. gr.) for 10 hours on a steam bath, shaking hourly.

(a = surface soil; b = subsoil.)

Soil No:	Insoluble	K_2O	Na_2O	CaO	MgO	Mn_2O_3	Fe_2O_3	Al_2O_3	P_2O_5	SO_3	CO_2	Nitric N	Total N	C	H	Total K_2O	Total P_2O_5
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	per cent	Per cent	Per cent	per cent	Per cent	Per cent	Per cent	per cent	Per cent	Per cent
1 (a	77.500	.554	.127	.955	1.052	.055	4.640	6.920	.230	.100	( )	( )	( )	( )	( )	1.768	.384
1 (b	77.680	.480	.283	1.415	1.661	.085	5.280	7.108	.147	.098	( )	( )	( )	( )	( )	1.905	.281
2 (a	88.292	.161	.063	.210	.247	.015	1.872	3.913	.066	.053	.037	( )	.074	1.850	( )	1.350	.102
2 (b	90.691	.164	.067	.170	.234	( )	1.887	3.749	.042	.023	.015	( )	.047	.750	.32	1.490	.064
3 (a	79.809	.525	.180	.610	.643	.110	3.440	5.569	.106	.081	( )	( )	.181	3.270	.71	( )	( )
3 (b	79.604	.580	.167	.520	.886	.065	4.200	6.935	.085	.053	.051	( )	.093	1.840	.67	( )	( )
4 (a	80.765	.496	.116	.465	.450	.045	3.280	5.254	.166	.069	.021	.0017	.213	3.420	.65	1.974	.192
4 (b	83.692	.425	.119	.350	.518	.050	3.480	5.187	.088	.043	.012	.0047	.111	1.780	.54	3.018	.211
5 (a	77.320	.405	.140	1.050	.695	.030	3.440	5.507	.153	.059	.135	.0029	.235	4.240	.75	1.752	.205
5 (b	81.920	.337	.116	.790	.585	.040	3.120	4.618	.137	.044	.068	.0024	.168	3.180	.62	1.829	.160
6 (a	80.553	.643	.119	.575	.501	.025	2.880	5.981	.089	.042	.054	( )	.174	3.400	.66	2.418	.14[illegible]
6 (b	80.080	.567	.212	.560	.776	.025	3.560	7.077	.073	.030	.030	.0017	.139	2.150	.65	2.450	.089
7 (a	83.555	.153	.122	.525	.558	.015	3.880	4.476	.144	.063	.053	.0023	.114	2.760	.52	1.527	.409
7 (b	87.077	.240	.090	.660	.822	.025	4.080	4.345	.087	.054	.030	.0017	.028	.540	.28	1.637	.224
8 (a	89.479	.118	.043	.490	.275	.037	1.631	1.702	.062	.041	.080	.0011	.126	2.960	.44	1.585	.096
8 (b	91.999	.246	.055	.340	.474	.025	2.084	2.840	.041	.030	.040	.0006	.017	.460	.21	1.553	.096
9 (a	84.692	.272	.078	.405	.055	.055	3.136	3.878	.121	.068	.102	.0046	.147	2.320	.61	1.570	.134
9 (b	87.287	.259	.073	.170	.411	.135	3.290	3.992	.094	.046	.046	.0006	.056	1.160	.41	1.690	.134

Table 39.-- Continued

10	a	80.715	.731	.125	.870	.907	.010	3.960	5.455	.185	.076	( )	( )	( )	( )	( )	4.536	.275
	b	71.270	.642	.291	7.715	2.010	.045	3.960	5.214	.176	.223	( )	( )	( )	( )	( )	2.403	.281
11	a	85.525	.321	.047	.250	.518	.070	3.000	3.536	.189	.045	.067	.0017	.122	2.810	.51	1.751	.281
	a	88.620	.351	.122	.140	.585	.040	3.320	4.057	.153	.046	.059	.0011	.0373	.860	.35	1.867	.243
12	a																	
	b																	
13	a	84.195	.390	.098	.665	.628	.030	2.720	3.817	.153	.107	( )	( )	( )	( )	( )	2.156	.179
	b	80.965	.397	.082	3.105	1.130	.035	3.000	4.890	.150	.068	( )	( )	( )	( )	( )	2.320	.198
14	a	93.580	.093	.051	.175	.162	.050	.800	1.788	.032	.034	.054	( )	.077	1.150	.27	1.062	.083
	b	84.345	.311	.029	.450	.608	.025	2.480	8.088	.032	.025	.005	.0006	.051	.640	.59	.935	.119
15	a	88.252	.230	.047	.405	.412	.072	1.756	3.229	.125	.050	.077	( )	.090	2.120	.41	1.970	.162
	b	91.472	.226	.072	.240	.411	.062	1.968	3.185	.077	.026	.094	( )	.021	.450	.25	1.708	.230
16	a	77.408	.977	.150	.150	1.192	.060	5.336	9.589	.120	.023	.054	.0011	.025	.380	.59	1.676	.211
	b																	

Table 40.-- Chemical composition of cultivated soils digesting 10 grams of sample in hydrochloric acid (1.115 sp. gr.) for 10 hours on a steam bath, shaking hourly.

(a = surface soil; b = subsoil.)

Soil No:	Insoluble	K_2O	Na_2O	CaO	MgO	Mn_2O_3	Fe_2O_3	Al_2O_3	P_2O_5	SO_3	CO_2	Nitric N	Total N	C	H	Total K_2O	Total P_2O_5
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
17(a	74.357	.594	.286	1.535	1.726	.050	5.640	7.697	.163	.068	( )	( )	( )	( )	( )	1.815	.339
(b	77.783	.509	.132	1.005	1.085	.130	4.840	6.372	.233	.083	( )	( )	( )	( )	( )	1.907	.300
18(a	72.015	.508	.115	.900	1.542	.050	5.976	9.397	.117	.111	.044	.0035	.140	2.720	.86	( )	( )
(b	81.201	.473	.231	1.020	1.490	.075	4.370	6.934	.056	.051	.045	.0015	.036	.730	.49	( )	( )
19(a	90.629	.156	.053	.230	.218	.020	1.476	2.945	.070	.043	.048	.0011	.095	1.580	.28	1.494	.070
(b	91.221	.193	.061	.157	.248	.040	1.622	3.412	.051	.018	.024	.0017	.046	.820	.31	1.565	.083
20(a	74.698	.479	.127	1.455	.989	.077	3.472	6.348	.185	.109	.068	( )	.301	4.950	.95	1.402	.275
(b	81.094	.544	.129	1.025	1.102	.065	3.900	6.644	.106	.038	.029	( )	.055	1.290	.61	( )	( )
21(a	81.970	.384	.114	.370	.450	.040	3.400	5.370	.105	.047	.010	.0024	.158	2.590	.60	1.856	.160
(b	81.510	.402	.085	.370	.651	.015	4.040	6.592	.093	.043	.005	.0017	.115	1.690	.55	1.640	.24
22(a	76.480	.365	.125	1.185	.662	.025	3.040	5.232	.093	.081	.014	.0049	.297	5.510	.85	1.890	.294
(b	80.110	.398	.140	1.015	.792	.015	3.520	6.101	.064	.037	.011	.0018	.125	2.510	.61	2.300	.128
23(a	80.605	.766	.178	.675	.615	.050	2.920	5.527	.128	.054	.048	.0011	.173	3.380	.66	2.491	.192
(b	79.813	.733	.127	.525	.687	.040	3.640	7.160	.090	.068	.030	.0024	.111	2.030	.61	2.592	.147
24(a	84.307	.216	.095	.680	.707	.040	3.920	4.715	.105	.051	.044	.0017	.116	1.950	.45	1.590	.371
(b	86.575	.146	.108	.570	.664	.020	3.880	4.460	.080	.063	.040	.0011	.048	1.270	.37	1.720	.217

Table 40.— Continued

25 (a	88.666:	.134:	.039:	.405:	.281:	.032:	1.746:	2.143:	.066:	.038:	.050:	.0029:	.096:	2.680:	.40:	1.247:	.102:
(b	92.940:	.180:	.092:	.310:	.434:	.032:	1.930:	2.430:	.035:	.014:	.035:	.0011:	.017:	.450:	.17:	1.570:	.102:
26 (a	85.724:	.370:	.082:	.505:	.366:	.055:	2.654:	3.554:	.160:	.083:	.056:	.0077:	.133:	2.580:	.54:	1.745:	.153:
(b	87.330:	.274:	.077:	.315:	.342:	.085:	2.846:	4.459:	.075:	.013:	.059:	.0029:	.055:	1.010:	.47:	1.603:	.134:
27 (a	80.570:	.747:	.132:	.970:	1.105:	.040:	4.280:	6.119:	.176:	.073:	( ):	( ):	( ):	( ):	( ):	( ):	(
(b	71.016:	.518:	.190:	8.640:	1.825:	.045:	3.760:	5.129:	.156:	.091:	( ):	( ):	( ):	( ):	( ):	( ):	( ):
28 (a	86.750:	.246:	.111:	.125:	.549:	.040:	3.040:	3.635:	.205:	.066:	.061:	.0028:	.105:	2.080:	.44:	1.805:	.313:
(b	87.085:	.355:	.135:	.175:	.810:	.040:	4.160:	4.423:	.147:	.029:	.031:	.0017:	.042:	.056:	.36:	2.361:	.236:
29 (a																	
(b																	
30 (a	86.305:	.365:	.071:	.710:	..585:	.040:	2.360:	2.923:	.147:	.085:	( ):	( ):	( ):	( ):	( ):	2.190:	.166:
(b	80.323:	.384:	.100:	4.000:	1.231:	.065:	2.880:	4.336:	.134:	.081:	( ):	( ):	( ):	( ):	( ):	1.970:	.147:
31 (a	94.330:	.053:	.008:	.150:	.104:	.005:	.800:	1.820:	.035:	.022:	.016:	.0046:	.068:	1.010:	.25:	1.095:	.089:
(b	82.435:	.225:	.172:	.675:	.525:	.050:	2.720:	7.792:	.038:	.012:	.074:	.0012:	.071:	.960:	.51:	.818:	.109:
32 (a	87.644:	.295:	.060:	.535:	.457:	.085:	2.094:	3.113:	.163:	.040:	.073:	.0011:	.105:	2.060:	.43:	1.510:	.262:
(b	89.308:	.364:	.067:	.400:	.564:	.090:	2.576:	3.877:	.142:	.024:	.046:	.0006:	.031:	.650:	.38:	1.713:	.25

Table 41.-- A comparison of the cropping efficiency of the oats and the total nitrogen and mineral matter content of the soils on which they were grown (mineral matter soluble in strong hydrochloric matter being considered.[a/]

(a = surface soil; b = subsoil.)

Soil No:	Complete analysis	K_2O, P_2O_5, N, CaO	K_2O, P_2O_5, N	K_2O, P_2O_5	K_2O, N	P_2O_5, N	K_2O	P_2O_5	N	Crop rank
23a	13	5	2	6	1	8	1	18	7	1
15a	26	25	27	25	26	23	25	19	26	2
6a	11	11	8	15	3	16	5	26	6	3
9a	20	22	21	24	17	14	23	20	11	4
32a	25	18	20	18	21	15	22	11	21	5
10a	14	4	3	4	8	5	4	6	12	6
3a	10	12	9	14	4	13	9	22	5	7
22a	4	10	11	23	10	11	17	24	2	8
18a	1	14	13	16	12	19	11	21	13	9
25a	29	30	30	31	30	30	31	30	24	10
8a	30	28	28	32	24	29	32	31	15	11
13a	19	8	7	12	9	4	15	13	4	12
4a	15	7	6	7	6	3	12	9	3	13
20a	3	2	5	5	5	1	14	5	1	14
2a	27	31	31	30	31	31	28	29	29	15
14a	33	32	33	33	33	32	33	33	28	16
11a	22	21	16	8	19	7	21	4	16	17
7a	18	20	25	26	23	18	30	16	17	18
11b	28	26	26	13	29	24	19	12	34	19
30a	23	24	23	17	25	23	18	15	30	20
5b	16	15	14	21	14	10	20	17	9	21
17a	2	29	15	4	20	22	6	10	33	22
19a	31	29	29	28	27	28	29	28	23	23
21a	17	17	18	22	17	13	16	23	10	24
27a	12	3	4	1	7	6	2	7	14	25
34b	21	27	25	20	28	21	26	8	27	26
1b	6	13	17	10	18	20	13	14	22	27
31a	34	34	34	34	34	34	34	34	31	28
1a	5	1	1	2	2	2	8	2	8	29
28a	24	23	19	9	22	12	24	3	20	30
23b	9	16	12	11	11	24	3	25	18	31
17b	7	9	10	3	13	9	10	1	19	32
19b	32	33	32	29	32	33	27	32	32	33
3b	8	19	22	19	16	27	7	27	5	34
				SUMMARY						
Division of table for comparison	Results as shown by actual determination									Theoretical number
	Number of soils in division named reaching theoretical rating.									
First half	8	9	9	9	9	11	8	5	12	17
First third	4	4	5	2	5	3	5	2	5	11
First fourth	2	2	3	2	4	2	4	1	4	8 1/2

[a/] The first and last columns show the soils arranged in order of their crop value, the most productive soil being No.1. The intervening columns show the relative position of the soils with regard to their content of the mineral constituents of the soils named in the respective columns.

Table 42.-- Parts per million of potash and phosphoric acid determined in virgin soils by the citric[a/] acid and hydrochloric[b/] acid methods.

(a = surface soil; b = subsoil.)

Soil No:		1 per cent citric acid		N/5 hydrochloric acid	
		P_2O_5	K_2O	P_2O_5	K_2O
1	a	305	119	210	350
	b	223	40	140	130
2	a	64	121	30	250
	b	25	73	10	170
3	a	51	127		
	b	32	91		20
4	a	71	81	20	210
	b	62	42	10	150
5	a	153	62	90	200
	b	63	37		
6	a	27	214	90	480
	b		160		
7	a	201	43	150	
	b	122	10	160	40
8	a	79	105	70	180
	b	35	46		
9	a	90	63	40	150
	b	43	37	10	130
10	a	192	335	410	770
	b	110	43		
11	a	385	400	400	590
	b	260	88	180	140
12	a	170	32		
	b	15	51		
13	a	51	93	140	200
	b	7	32		
14	a	40	51		
	b	15	28		80
15	a	426	68	300	150
	b	200	345	180	120
16	a	23	116		

a/ 200 grams of sample per liter of 1 per cent acid, digested for 5 hours at 40° C, shaken continuously.

b/ 100 grams of sample per liter of N/5 acid digested 5 hours at 30° C, shaken continuously.

Table 43.-- Parts per million of potash and phosphoric acid determined in cultivated soils by the citric[a/] and hydrochloric[b/] acid methods.

(a = surface soil; b = subsoil.)

Soil No:	1 Per cent citric acid		N/5 hydrochloric acid	
	P_2O_5	K_2O	P_2O_5	K_2O
17 a	331	156	260	410
17 b	374	90	240	320
18 a	18	82	20	170
18 b	54	21	:	:
19 a	81	41	30	100
19 b	48	37	:	:
20 a	242	41	:	:
20 b	154	26	420	170
21 a	61	32	:	:
21 b	35	38	10	160
22 a	144	50	126	130
22 b	37	30	70	150
23 a	270	840	260	1420
23 b	48	274	40	120
24 a	191	24	90	70
24 b	-	15	120	30
25 a	110	146	100	250
25 b	28	178	:	:
26 a	346	502	250	760
26 b	42	103	20	280
27 a	172	157	320	430
27 b	3	23	:	:
28 a	400	240	480	340
28 b	165	143	270	260
29 a	408	192	:	:
29 b	135	46	:	:
30 a	51	71	160	170
30 b	3	42	100	130
31 a	37	86	30	160
31 b	30	33	20	120
32 a	600	90	:	:
32 b	309	64	380	160

a/ 200 grams of sample per liter of 1 per cent acid, digested for 5 hours at 40° C, shaken continuously.

b/ 100 grams of sample per liter of N/5 acid digested 5 hours at 30° C, shaken continuously.

Table 44.-- Potash and phosphoric acid content of soils determined by the citric acid method under varying conditions of digestion, all being made on water bath and shaken every 15 minutes.

(a = surface soil; b = subsoil.)

Soil	Weight of sample	Time digested	Quantity of solvent	Citric acid strength	Temperature of digestion	P_2O_5	K_2O
	grams	hours	liters	per cent	degrees	per cent	per cent
34a	200	5	1	1	30	0.011	0.007
34a	200	5	2	1	30	.012	.008
34a	200	5	3	1	30	.014	.008
34a	200	5	1	2	30	.012	.007
34a	200	5	2	2	30	.013	.007
34a	200	5	3	2	30	.013	.008
34a	200	5	1	1	40	.022	.008
34a	200	5	2	1	40	.022	.008
34a	200	5	3	1	40	.026	.009
34a	200	5	1	2	40	.024	.008
34a	200	5	2	2	40	.022	.008
34a	200	5	3	2	40	.030	.008

Table 45.-- Potash and phosphoric acid content of soils determined by the oxalic acid method under varying conditions of digestion, all being made at room temperature and shaken every 15 minutes.

(a = surface soil; b = subsoil.)

Soil	Weight of sample	Time digested	Quantity of solvent	Oxalic acid	Temperature of digestion	P_2O_5	K_2O
	grams	hours	liters	grams per liter	degrees	per cent	per cent
34a	200	1	1	6.3	23	0.027	0.015
34a	200	2	1	6.3	23	.027	.012
34a	200	3	1	6.3	23	.027	.013
34a	200	4	1	6.3	23	.027	.013
34a	200	5	1	6.3	23	.027	.012
34a	200	1	2	6.3	23	.043	.013
34a	200	2	2	6.3	23	.048	.012
34a	200	3	2	6.3	23	.052	.012
34a	200	4	2	6.3	23	.055	.012

Table 46.-- The solubility of phosphoric acid and potash in soils expressed in parts per million, as determined in hydrochloric acid of varying strength, using 200 grams of the sample per liter, and digesting for five hours at 40° C with continuous shaking.

(a = surface soil; b = subsoil.)

Soil No:	Phosphoric acid (P_2O_5)				Potash (K_2O)			
	N/25	N/50	N/100	N/200	N/25	N/50	N/100	N/200
8a	24:	13:	13:	9:	182:	():	():	45:
15a	60:	():	():	18:	107:	80:	64:	60:
3b	2:	1:	1:	1:	168:	115:	69:	69:
1a	105:	63:	35:	16:	( ):	( ):	():	65:
3a	6:	6:	5:	5:	( ):	191:	153:	105:
10a	280:	114:	24:	10:	425:	310:	235:	175:
11a	48:	27:	20:	18:	( ):	405:	317:	235:
13a	50:	20:	5:	4:	( ):	( ):	147:	66:
14a	16:	15:	15:	11:	76:	74:	58:	47:
17a	122:	112:	57:	25:	225:	159:	110:	84:
21a	2:	2:	2:	1:	( ):	( ):	67:	27:
23a	57:	42:	42:	33:	920:	705:	560:	525:
28a	44:	44:	17:	10:	( ):	283:	238:	171:
29a	74:	40:	26:	25:	377:	191:	148:	118:
30a:	44:	25:	5:	2:	( ):	72:	50:	45:
31a	22:	19:	13:	13:	( ):	103:	88:	74:
32a	104:	68:	68:	68:	( ):	103:	74:	58:
17b	101:	64:	57:	25:	( ):	93:	88:	46:
23b	15:	10:	2:	1:	361:	280:	159:	166:
2a	( ):	2:	2:	2:	( ):	144:	129:	102:
6a	( ):	15:	10:	7:	( ):	223:	166:	144:
7a	( ):	6:	2:	1:	( ):	( ):	104:	( ):
8a[a]	( ):	8:	7:	4:	( ):	57:	55:	31:
9a[a]	( ):	70:	( ):	1:	( ):	131:	( ):	41:
11a[a]	( ):	21:	13:	12:	( ):	230:	173:	134:
12a	( ):	5:	5:	5:	( ):	44:	30:	28:
14a[b]	( ):	8:	8:	8:	( ):	61:	44:	37:
14a [a]	( ):	6:	4:	3:	( ):	56:	48:	38:
11b	( ):	30:	13:	3:	( ):	99:	90:	76:
17a[b]	( ):	91:	33:	21:	( ):	160:	105:	71:
23a[a]	( ):	25:	23:	13:	( ):	626:	452:	356:
25a	( ):	10:	6:	5:	( ):	171:	171:	170:
32a[b]	( ):	62:	55:	42:	( ):	95:	74:	46:
32a[a]	( ):	44:	44:	27:	( ):	88:	72:	58:
17b[b]	( ):	60:	16:	5:	( ):	178:	78:	66:
23b[a]	( ):	2:	1:	1:	( ):	233:	171:	147:
39a	( ):	1:	1:	1:	( ):	28:	28:	22:
41a	( ):	4:	2:	2:	( ):	27:	25:	17:
42a	( ):	1:	1:	1:	( ):	199:	180:	160:
43a	( ):	15:	10:	6:	( ):	209:	156:	127:

[a] Third cropping
[b] Second cropping

Table 47.-- Comparison of the number of parts per million of phosphoric acid and potash removed by oat crops from different soils with the amounts soluble in N/200 hydrochloric acid under definite conditions.

(a = surface soil; b = subsoil.)

Soil No:	Soluble in N/200 HCl: P_2O_5	Soluble in N/200 HCl: K_2O	Removed by a crop: P_2O_5	Removed by a crop: K_2O	Plot No:	Fertilization
		VIRGIN SOILS				
1a	16	65	16	60		
1a[a]	8	84	10	36		
2a	2	102	4	42		
2a[a]	2	92	5	43		
3a	5	87	8	79		
4a	5	77	5	42		
6a	7	144	7	98		
6a[a]	7	101	5	55		
7a	1	27	7	26		
8a	9	45	7	40		
8a[a]	4	31	4	20		
9a[a]	2	40	4	44		
9a[b]	1	41	4	37		
10a	10	175	15	82		
11a	18	235	17	76		
11a[b]	12	134	12	36		
12a	5	28	12	24		
13a	4	66	5	58		
14a	11	47	5	44		
14a[a]	8	37	4	29		
14a[b]	3	38	3	20		
15a	18	60	18	67		
15a[a]	16	54	19	39		
		CULTIVATED SOILS				
17a	25	84	14	62		
17a[a]	21	71	15	21		
18a	2	50	5	15		
19a	1	47	2	38		
20a[a]	14	24	15	53		
21a	1	15	5	18		
22a	20	30	21	58		
23a	31	402	29	98		
23a[a]	13	366	16	92		
25a	5	170	5	39		
25a[a]	4	67	10	53		
27a	9	88	12	46		
28a	10	171	11	34		
29a	25	116	27	99		
30a	2	45	5	46		
31a	11	61	13	56		
32a	68 c/	58	6 c/	72		
32a[a]	42	46	20	39		
32a[b]	27	58	19	38		
		VIRGIN SUBSOILS				
1b	16	20	16	41		
1b[b]	18	69	14	24		
3b	1	69	2	19		
5b[a]	4	20	6	33		
11b	3	76	11	72		

Table 47.-- Continued

		CULTIVATED SUBSOILS				
17b	25	46	6	37		
17b[a]	5	34	5	7		
19b[a]	1	31	2	10		
23b	1	166	5	45		
23b[b]	1	147	3	19		
29b	1	16	1	11		
		ROTHAMSTED SOILS				
37a	1	27	3	21	W10a	
38a	5	27	10	30	W11	P
39a	1	22	4	24	B1a	
40a	4	147	15	76	W13	K+P
41a	2	17	13	29	B2a	P
42a	1	160	6	34	B3a	K
43a	6	127	16	64	B4a	K+P
44a	1	35	4	30	W3	

AVERAGES

Phosphoric acid removed

Soil	By solvent	By crop
Virgin surface	7.6	8.5
Cultivated surface	14.5	13.2
All subsoils	6.9	6.5
All samples	9.8	9.7
Rothamsted	3.0	10.0

a/ Second planting
b/ Third planting
c/ Omitting 32a from average

Table 48.-- A comparison of the amounts of phosphoric acid and potash removed from the soil by various solvents and by an oat crop.

(a = surface soil; b = subsoil.)

Soil	Parts per million of P_2O_5					Parts per million of K_2O						
	N/5 HCl[a]	Ammonium citrate[b]	Citric acid 1 per cent[c]	N/200 HCl	Taken off by crops	N/5 HCl	Ammonium citrate	Citric acid 1 per cent	N/200 HCl	Taken off by crops	NH_4Cl[d]	N/5 $CaCl_2$[e]
5a	90	150	110		16	200	190	120		51	220	110
6a	80	80	60	7	7	470	600	270	144	98	500	390
15a	330	110	290	18	18	160	100	70	60	67	160	230
17a	200	60	320	25	14	430	420	270	84	62	430	260
18a	20	230	200	2	5	170	190	90	50	15	210	220
25a	90	150	70	5	5	220	260	170	170	39	230	340
7b	160	50	70		2	70	90	20		4	50	70
17b	160	300	350	5	6	330	850	120	34	7	390	150
20b	350	100	270		2	190	190	50		10	160	90
32b	130	230	340	7	13	160	180	70	35	34	160	120

NOTE- 100 grams of soil per liter were shaken continuously for 5 hours at 30° C in all cases with the exception of the N/200 HCl method, when 200 grams per liter and 40° C were used.

a No allowance for basicity;-- U. S. Dept. of Agri., Bureau of Chemistry; Bull. 49, p. 82.
b A. O. A. C. fertilizer solution, full strength; ibid, Bull. 46, p. 11.
c Dyer, Jour. Chem. Soc., 1894, (Trans.), Vol. 65, p. 115.
d Heuston, U. S. Dept. Agri., Bureau of Chemistry, Bull. 51, p. 75.
e Ibid, Bull. 56, p. 50.

Table 49.— Average yields of nitrogen, phosphoric acid, and potash in the principal grain and fodder crops.

Crop	Pounds per acre		
	Nitrogen N	Phosphoric acid P_2O_5	Potash K_2O
Oats	72	30	82
Barley	69	29	54
Wheat	94	38	49
Rye	61	35	64
Peas	142	41	70
Beans	213	56	119
Sugar beets	64	34	133
Mangolds	132	51	291
Swedish turnips	120	65	178
Potatoes	89	45	142
Meadow hay	70	19	72
Clover hay	100	30	143
Alsike clover	134	23	62
Fodder vetches	102	29	88

Table 50.— Yields of straw and grain in some of the large oat crops of 1900.

(a = surface soil; b = subsoil.)

Soil No	Weight straw	Weight seed	Soil No	Weight straw	Weight seed
	grams	grams		grams	grams
1a	84.6	3.11	23a	88.8	.03
2a	67.7	2.32	25a	38.5	.40
5a	71.2	.18	28a	85.8	.57
6a	81.8	.57	29a	84.0	.87
8a	40.1	.12	30a	88.1	.84
9a	64.7	.34	31a	58.7	.68
10a	79.9	.11	32a	85.2	.74
11a	93.1	2.82	34a	35.7	.00
13a	75.5	1.07	35a	58.5	1.20
14a	82.4	1.54	1b	73.0	2.13
17a	73.5	2.16	5b	81.1	.60
21a	49.1	1.81	17b	51.8	4.90
22a	67.5	.00			

Table 51.-- Plant food (expressed in parts per million) added to Florida muck soils on which oats were grown.

(a = surface soil; b = subsoil.)

Pot No:	Soil No:	1895			1899				1901:	1902			
			P_2O_5			K_2O	P_2O_5	CaO			P_2O_5		
		Fertilizer	Total	Available	Fertilizer				Fertilizer	Total	Available	CaO	
135	45a				Sodium phosphate		35						
136	45a	Raw rock	550	100	Sodium phosphate		35	5000	Raw rock	300	55		
137	45a	Slag	360	160	Potassium phosphate	27	17	5000	Slag	100	44		
138	45a	Acid rock	300	290	Potassium phosphate	27	17	5000	Acid phosphate		90		
139	46a				Sodium phosphate		35					10000	
140	46a	Raw rock	550	100	Sodium phosphate		35	5000	Raw rock	300	55		
141	46a	Slag	360	160	Potassium phosphate	27	17	5000	Slag	100	44		
142	46a	Acid rock	300	290	Potassium phosphate	27	17	5000	Acid phosphate		90		
143	47a							5000	Acid phosphate		90		
144	48a												
145	48a	Raw rock	550	100				5000	Raw rock	300	55		
146	48a	Slag	360	160				5000	Slag	100	44		

Table 52.— Plant food (expressed in parts per million) added to virgin soils on which oats were grown.

(a = surface soil; b = subsoil.)

Pot	Soil	1901							1902				
		Nitrogen as			Potash as		Phos. acid as	Lime	Nitrogen as		Potash as	Phos. acid	Lime
		$NaNO_3$	NH_4Cl, $(NH_4)_2SO_4$		K_2SO_4		$CaH_4(PO_4)_2$	CaO	NH_4NO_3 Amic.	NH_4NO_3 Nitric	K_2SO_4	$CaH_4(PO_4)_2$	CaO
		1st crop	1st crop	2nd crop	1st crop	2nd crop	1st crop	2nd crop					
1	1 (a												
31	1 (b												
3	2 (a	21		9					10	10		90	1590
33	2 (b	18		7			77	25	9	9		77	2800
5	3 (a											97	1720
35	3 (b						88	40	1590			88	
9	4 (a						130	45				130	
38	4 (b						84	28					
10	5 (a												
39	5 (b								1630				
7	6 (a											97	1750
41	6 (b						97	32	1740				
12	7 (a	21		9	40	40			10	10	40		1620
44	7 (b	21		9	40	40							
14	8 (a						75	25				75	1350
46	8 (b	15		6			65	21					

Table 52.-- Continued

16	9	(a											1630
48		(b					81	27		10	10	81	3000
18	10	(a											
50		(b					84	28	1520				
19	11	(a											1340
51		(b		7	7				1340	9	9		
20	12	(a											
52[a]		(b				38	38		1530				
22	13	(a											
55		(b		7	7				1260				
25	14	(a	18		8					9	9	78	1400
58[a]		(b					84	28	1520				
27	15	(a											1400
60		(b	18		7	35	35			9	9	35	
127	16	(a	18		7			77	25	9	9	77	

a/ 1500 parts CaO added in 1899.

Table 53.-- Plant food (expressed in parts per million) added to cultivated soils on which oats were grown.

(a = surface soil; b = subsoil.)

Pot	Soil	1901							1902				
		Nitrogen as			Potash as		Phos. acid as		Lime	Nitrogen as		Potash as	Phos. acid	Lime
		$NaNO_3$	NH_4Cl, $(NH_4)_3SO_4$		K_2SO_4		$CaH_4(PO_4)_2$		CaO	NH_4NO_3 Amic.	NH_4NO_3 Nitric	K_2SO_4	$CaH_4(PO_4)_2$	CaO
		1st crop	1st crop	2nd crop	1st crop	2nd crop	1st crop	2nd crop						
63	17 (a													
93	17 (b													
65	18 (a													
95	18 (b						80	27	1450				80	
69	19 (a								1450					
101	19 (b						80	27	1450				80	8400
70	20 (a													
98	20 (b		9	9						10	10	42		
73	21 (a						84	28					84	1530
102	21 (b						84	28						
74	22 (a													1810
103	22 (b													
76	23 (a													
104	23 (b												88	
78	24 (a	19		8	37	37				9	9	37		
106	24 (b	20		9	38	38								
80	25 (a						75	25		9	9			770
108	25 (b	15		6			60	20						

Table 53.-- Continued

82:	26 (a:												
109:	(b:					84:	28:						
84:	27 (a:												
111:	(b:					80:	25:	1430:					
85:	28 (a:							1300:					
112:	(b:		9:	9:									
86:	29 (a:												
113:	(b:												
87:	30 (a:												
118:	(b:					72:	23:						
89:	31 (a:	19:		8:		80:	27:		9:	9:		80:	1450:
120:	(b:	33:		14:		140:	46:	2500:					
90:	32 (a:												1550:
121:	(b:	19:		8:									
129:	33a	16:		7:					8:	8:			1210:
29:	34a							1500:					
131:	35a												
151:	36a							400:					
156:	37a		12:	6:					7:	7:			
158:	38a		12:	6:		60:	20:		7:	7:		60:	

Table 53.-- Continued

160:39a	:	6:	6:	:	:	:	:	:	7:	7:	:	:	:
162:40a	:	12:	6:	28:	28:	60:	20:	:	7:	7:	28:	60:	:
164:41a	:	6:	6:	:	:	60:	20:	:	7:	7:	:	60:	:
166:42a	:	6:	6:	28:	28:	:	:	:	7:	7:	28:	:	:
168:43a	:	6:	6:	28:	28:	60:	20:	:	7:	7:	28:	60:	:
170:44a	:	:	:	:	:	:	:	:	:	:	:	:	:

Table 54.-- Reaction of soils prior to the planting of cowpeas in 1902.[a]

(a = surface soil; b = subsoil.)

Virgin soils			Cultivated soils		
Pot No:	Soil No:	Reaction	Pot No:	Soil No:	Reaction
2	1a	acid	64	17a	alkaline
32	1b	alkaline	94	17b	
4	2a	acid	67	18a	acid
34	2b	do	96	18b	alkaline
6	3a	alkaline	71	20a	alkaline
36	3b	acid	99	20b	do
11	5a	alkaline	75	22a	alkaline
40	5b	do	--	22b	
8	6a	acid	77	23a	alkaline
42	6b		105	23b	do
13	7a	acid	79	24a	acid
45	7b		107	24b	do
15	8a	alkaline	81	25a	alkaline
47	8b	do	--	25b	
17	9a		83	26a	
49	9b	acid	110	26b	
21	12a	alkaline	88	30a	alkaline
--	12b		119	30b	do
23	13a	alkaline	91	32a	alkaline
56	13b		122	32b	do
26	14a	acid	130	33a	
59	14b				
			30	34a	
28	15a	acid			
61	15b	do	157	37a	alkaline
128	16a	alkaline	159	38a	alkaline
			161	39a	alkaline
			163	40a	alkaline
			165	41a	alkaline
			167	42a	alkaline
			169	43a	alkaline
			171	44a	alkaline
			148	49a	alkaline

[a] Ten grams of soil are treated with 100 cc of distilled water in a Jena flask and allowed to stand over night. 50 cc of the supernatant liquid are carefully drawn off and boiled with a few drops of phenolphthalein in a covered Jena beaker until the appearance of the pink color, or to a volume of about 5 cc with no development of color. Pink indicates alkaline. No color, acid or neutral.

Table 55.— Plant food (expressed in parts per million) added to virgin soils on which cowpeas were grown in 1901 and 1902.

(a = surface soil; b = subsoil.)

Pot No:	Soil No:	1901					1902		
		Potash as K_2SO_4		Phos. acid as $CaH_4(PO_4)_2$		Lime CaO	Potash as K_2SO_4	Phosphoric acid as $CaH_4(PO_4)_2$	Lime CaO
		1st crop	2nd crop	1st crop	2nd crop				
2	1 (a								1380
32	1 (b								
4	2 (a							92	1650
34	2 (b			85	28			85	1530
6	3 (a							97	1730
36	3 (b			85	28			85	1580
11	5 (a								
40	5 (b								1730
8	6 (a							90	1610
42	6 (b			98	32				
13	7 (a	42	42				42		
45	7 (b	38	38						1650
15	8 (a			75	25			25	1310
47	8 (b			70	23				
17	9 (a					1560			1560
49	9 (b			84	28			28	3000
21	12 (a								
--	12 (b								

Table 55.— Continued

23	13(a								1350
56	13(b								
26	14(a							75	1320
59	14(b			97	32				
28	15(a								1520
61	15(b		33	75	25		33	75	2600
128	16a								

Table 56.— Plant food (expressed in parts per million) added to cultivated soils on which cowpeas were grown in 1901 and 1902.
(a = surface soil; b = subsoil.)

Pot No	Soil No	1901					1902			
		Potash as K_2SO_4		Phos. acid as $CaH_4(PO_4)_2$		Lime CaO	Potash as K_2SO_4	Phos. acid as $CaH_4(PO_4)_2$	Lime CaO
		1st crop	2nd crop	1st crop	2nd crop				
64	17 (a								1540
94	17 (b								
67	18 (a					1720			1720
96	18 (b			90	30	1600		90	
71	20 (a								
99	20 (b								
75	22 (a								2000
--	22 (b								
77	23 (a								
105	23 (b							84	1530
79	24 (a	35	35				35		
107	24 (b	35	35						
81	25 (a			75	25				1000
--	25 (b								
83	26 (a								
110	26 (b			75	25				
88	30 (a								
119	30 (b			97	32				

Table 56.-- Continued

122 91	32 (a (b								1480
130	33a								
30	34a					1500			1500
157	37a								
159	38a				60	20		60	
161	39a								
163	40a		27				27	60	
165	41a				60	20		60	
167	42a		27				27		
169	43a		27	27	60	20	27	60	
171	44a								
148	49a					1400			

Table 56-